

MODELING OF A MULTILEAF COLLIMATOR

By

SIYONG KIM

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This dissertation is dedicated to
my loving wife, Gyejin,
and darling daughters, Minkyung and Minna,
for everything we have shared.

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By

Siyong Kim

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Chairman: Jatinder R. Palta

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A comprehensive physics model of a multileaf collimator (MLC) field for treatment planning was developed. Specifically, an MLC user interface module that includes a geometric optimization tool and a general method of in-air output factor calculation were developed.

An automatic tool for optimization of MLC conformation is needed to realize the potential benefits of MLC. It is also necessary that a radiation therapy treatment planning (RTTP) system is capable of modeling MLC completely. An MLC geometric optimization and user interface module was developed. The planning time has been reduced significantly by incorporating the MLC module into the main RTTP system, Radiation Oncology Computer System (ROCS).

The dosimetric parameter that has the most profound effect on the accuracy of the dose delivered with an MLC is the change in the in-air output factor that occurs with field shaping. It has been reported that the conventional method of calculating an in-air output factor cannot be used for MLC shaped fields accurately. Therefore, it is necessary to develop algorithms that allow accurate calculation of the in-air output factor. A generalized solution for an in-air output factor calculation was developed. Three major contributors of scatter to the in-air output--flattening filter, wedge, and tertiary collimator--were considered separately. By virtue of a field mapping method, in which a source plane field determined by detector's eye view is mapped into a detector plane field, no additional dosimetric data acquisition other than the standard data set for a range of square fields is required for the calculation of head scatter. Comparisons of in-air output factors between calculated and measured values show a good agreement for both open and wedge fields. For rectangular fields, a simple equivalent square formula was derived based on the configuration of a linear accelerator treatment head. This method predicts in-air output to within 1% accuracy. A two-effective-source algorithm was developed to account for the effect of source to detector distance on in-air output for wedge fields. Two effective sources, one for head scatter and the other for wedge scatter, were dealt with independently. Calculations provided less than 1% difference of in-air output factors from measurements. This approach offers the best comprehensive accuracy in radiation delivery with field shapes defined using MLC. This generalized model works equally well with fields shaped by any type of tertiary collimator and have the necessary framework to extend its application to intensity modulated radiation therapy.

CHAPTER 1 INTRODUCTION

General Introduction

The discovery of x-rays and radioactivity was promptly followed by its therapeutic application in the treatment of benign and malignant diseases. The first therapeutic use of x-rays is reported to have taken place on January 29, 1896, when a patient with carcinoma of the breast was treated with x-rays. By 1899, the first cancer, a basal cell epithelioma, had been cured by radiation. Nowadays, radiation therapy is used in approximately half of cancer patients either in a stand alone therapy or in combination with chemotherapy or surgery. Better cure rates with radiation therapy, preservation of organ and its function, and cosmesis can be easily attributed to technological gains in radiation physics and better insights into radiation biology and pathophysiology. The primary goal of radiation therapy is to produce the highest probability of local and regional tumor control with the lowest possible side effects. Most cancer cells, like other highly proliferating cells, are more sensitive to ionizing radiation than normal cells. This is the fundamental premise in radiation therapy. The difference, however, is not always large enough to guarantee successful treatment all the time. Therefore, significant effort has been expected in radiation therapy in developing means to conform the dose to the tumor cells while minimizing the dose to the normal cells, and to deliver the dose as accurately and safely as possible. Since the advent of radiation therapy, photon beams

have been used the most commonly. In the early days of radiation therapy, photon beams from x-ray tubes were the only sources of radiation available at that time. Most treatments were limited to diseases at shallow depths due to the lower penetrability of these x-rays. With the development of the cobalt machine with the use of sealed, high-activity ^{60}Co source in 1951 (Johns et al. 1952, Green & Errington 1952), radiation therapy techniques took a quantum leap. Although cobalt unit is still an important machine today, linear accelerators have become the most commonly used treatment machine in radiation therapy clinics. The developments of diagnostic modalities, such as CT (computed tomography) and MRI (magnetic resonance imaging) have dramatically increased the precision in localization of the tumor extensions and critical healthy tissues in three dimensions. A greater precision in localization of the tumor volume has been augmented by the computer controlled radiation therapy machines, equipped with multileaf collimator (MLC) that enable precise customized beam shaping (Brahme 1987).

Significance of The Multileaf Collimator System

The computer controlled MLC system is regarded as the state-of-the art method for generating arbitrary (and generally irregularly) shaped fields for radiation therapy. Progress in imaging modalities such as CT and MRI dramatically enhance the ability to differentiate and delineate the target volume and normal structures in three dimensions. Better information about tumor shapes is leading to a greater need for achieving conformal treatments. An MLC system is considered as the most versatile tool that is available for delivery of three-dimensional conformal treatment. An MLC system for

conformal therapy is still a research tool with its use limited to only a few academic centers. The MLC systems have also been used for shaping neutron beams. (Eenmaa et al. 1985, Chu & Bloch 1987, Brahme 1988, Wambersie 1990). An MLC system offers a number of other important advantages over conventional field shaping devices (Mohan 1992). First, an MLC can be used to implement computer-controlled dynamic or multi-segmented conformal treatments in which the field aperture for each segment or direction is automatically adjusted to conform to the shape of the target volume or to a desired shape. Second, an MLC can be used to modulate intensity across the two dimensional profile of a field. Third, an MLC eliminates the effort and cost of fabricating custom blocks such as used in conventional treatments within static fields. It also eliminates the need for storage space for blocks and blocking trays, and the effort required in lifting and mounting heavy blocks. The use of the MLC system for static fields provides savings in set-up time while reducing the probability of set-up mistakes.

There are some concerns in the field conformation with an MLC. An MLC can provide only a 'zigzag' approximation to the shape of the target volume because of the finite leaf edge dimension. This inevitable drawback of the MLC requires some change in the concept of beam collimation. It is important to realize that an MLC does not provide exact conformation to the target contour drawn by a physician. The degree of nonconformality depends on the direction of the leaf placement along the contour edge. Therefore, it is essential that there are methodologies available which allow optimized positioning of the leaves automatically around the target contour. More importantly this step should be completely incorporated within the treatment planning process.

Overview of MLC Systems

Motor-driven MLC systems have been in use since the mid-fifties (Mohan 1992, Webb 1993). These devices have become very popular within the past several years and many commercial MLCs (e.g., Siemens, Scanditronix MM50, Varian C-series, and Philips SL-series) are now readily available. The MLC systems provided by different vendors are different in design and thus have different dosimetric characteristics. There are two fundamentally different design concepts of MLC configuration. The first one incorporates the MLC as an integral part of the secondary collimator system, thus replacing either the upper or lower secondary collimator jaws. In the second design, the MLC is attached below the secondary collimator system as a tertiary collimator system. The advantage of the latter design is that repair of the MLC is relatively easier than an integral MLC, thus allowing the machine to be operated in a conventional mode even when the MLC is down. The disadvantage is that an enlarged treatment head reduces the collision free zone for certain clinical setups.

The Philips Medical System offers an MLC system that is an integral part of the secondary collimator system. In the Philips MLC, the MLC replaces the upper secondary collimator jaws. The travel of MLC leaves is parallel to the axis of rotation of the gantry, that is, in the y-direction. The MLC is augmented by a backup collimator which is located below the leaves and above the lower jaws. The purpose of backup collimator is to decrease the intensity of transmitted radiation through the MLC. Backup diaphragms are designed to move automatically to the edge position of the outermost withdrawn leaf. Because the vertical location of the MLC is close to the source, the range of motion of the

leaves is smaller in this configuration than compared to others. Consequently, it is possible to make a more compact treatment head. On the other hand, the leaf width is somewhat smaller and the tolerances on the dimensions of the leaves as well as the leaf travel are tighter than those for other configurations. Another concern from an engineering point of view is that gaps are inevitable between two adjacent leaves (to reduce friction) and opposite leaves (to prevent collision). If the mechanical gap distance is fixed, the irradiated area over the leakage radiation through the gap is larger when the position of the gap is closer to the source. Therefore, a more integrated leakage is expected for this configuration.

The configuration of the Scanditronix (Racetrack Microtron, MM50), Siemens, and General Electric (GE) MLC systems is very similar to the previous configuration except that the lower jaws are replaced with the MLC. In both the Scanditronix and the Siemens design, the leaf ends are straight and are focused on the x-ray source. The leaf sides are also matched to the beam divergence and that makes these leaves "double focused". The Scanditronix MLC is positioned at 31 cm from the isocenter with a maximum field size of $32 \times 40 \text{ cm}^2$ and a maximum over-center position of 5 cm. The width of the individual leaves at isocenter is 1.25 cm. The Siemens MLC consists of 29 opposed leaf pairs. While the two outer leaves of each leaf bank project to a width of 6.5 cm, the inner 27 leaf pairs project to a width of 1.0 cm at the isocenter plane. Each leaf is independently controlled and moves with the maximum velocity of 1.5 cm/sec. The projected field edge of each leaf can be withdrawn up to 20 cm away from the isocenter and can travel up to 10 cm across the isocenter. The leaves may be manually positioned

with an MLC hand control and these leaf-settings can be uploaded to an information management record and verification system. The GE configuration uses curved leaf ends and contains a secondary 'trimmer' similar to the Philips backup diaphragm. However, this trimmer is located above the upper jaws in the GE design.

In the Varian design, MLC is an add-on device that mounts to the existing clinical accelerator head thereby making it field retrofittable. The advantage of this design is that it is possible to avoid down-time in the event of a system malfunction. In this configuration, the leaves can be manually moved out of the field when a system failure occurs. Treatment can continue with replacement Cerrobend blocks. A total of 26 pairs of leaves can produce the maximum MLC field size of $26 \times 40 \text{ cm}^2$ at the isocenter plane. The newer model of the Varian MLC has 40 pairs of leaves which gives a maximum field size of $40 \times 40 \text{ cm}^2$. Each leaf can travel up to 16 cm beyond the isocenter with the maximum leaf speed of 1.5 cm/sec (5 cm/sec in new design). Since the MLC is located far from the source, the travel length of the leaves required to produce the same field size is longer than in other configurations, thus it enlarges the diameter of the treatment head. Clearance (from the bottom of the MLC to the isocenter) is 42.4 cm. Clearance can potentially be a minor problem in some clinical cases.

Another tertiary system is the Mimic device provided by NOMOS Corporation. This is designed to mount on the blocking tray of a linear accelerator. It collimates the x-ray field to a fan-beam which is dynamically modulated by short-stroke leaves as the gantry of the accelerator is rotated. The modulated fan beam irradiates a transverse plane

of the patient that is 2 cm thick. The leaves are either fully inserted into the beam or fully retracted, providing either full attenuation or no attenuation at a given gantry angle.

In general, the following attributes of an MLC system affect its dosimetric characteristics:

1) Leaf shape: Ideally one would like the leaves to be "double-focused", that is, leaves form a cone of irregular cross-section diverging from an apex located at the radiation source. The leaves travel on a spherical shell centered at the source. This type of MLC produces a sharp cut-off at the edge and is used by at least two of the manufacturers (Scanditronix and Siemens). However, double focusing is difficult to achieve from the engineering point of view. Therefore some manufacturers (Varian and Philips) use rounded leaf edges. The edge of each leaf is a section of a cylinder and the leaves travel in a plane perpendicular to the central ray. The purpose of rounded edges is to keep the transmission through the leaf constant regardless of its position with respect to the central ray. There are some potential problems with such designs: first, the light field may not coincide with the 50% width of the radiation field; secondly, the radiation field may shift as much as 5 mm when the leaves move from 0 to 20 cm.

2) Integral MLC vs. optional attachment: The integral MLC (such as those by Scanditronix and Philips) replaces one pair of jaws. In most instances, however,

the MLC is offered as an optional attachment (e.g., Varian). In an integral MLC, the leaves are at the same distance from the flattening filter and the source as the jaws they replace. Therefore, they affect the output in the same manner as the jaws. On the other hand, an MLC offered as optional attachment is farther away from the flattening filter and it affects the output in a manner similar to conventional blocks.

Many authors have studied general dosimetric characteristics of MLC systems, such as field-size dependence of output factors (Jordan & Williams 1994, Palta et al. 1996, Boyer et al. 1992), depth doses (Boyer et al. 1992, Huq et al. 1995, Palta et al. 1996), isodose distribution (Boyer et al. 1992, Zhu et al. 1992), penumbra (Galvin et al. 1992 and 1993, Boyer et al. 1992, LoSasso et al. 1993, Jordan & Williams 1994, Huq et al. 1995, Palta et al. 1996, Powlis et al. 1993), and leaf transmission data (Jordan & Williams 1994, Palta et al. 1996, Boyer et al. 1992, Huq et al. 1995, Galvin et al. 1993, Klein et al. 1995). The dosimetric parameter that has the most profound effect on the accuracy of dose delivered with an MLC is the change in output factor, especially the in-air output factor that occurs with field shaping.

In linear accelerators, the in-air output factor changes according to the collimator opening. The MLC, as a collimator system, also affects the characteristics of the in-air output factor. The conventional method of in-air output factor calculation can often have a significant discrepancy between the predicted and measured values when it is applied to

MLC systems. Therefore it is necessary to develop an accurate method of in-air output factor calculation that can be applied to MLC shaped fields.

The Aim of This Thesis

The aim of this work is to develop a physics model for treatment planning which describes the high energy photon beam collimated by an MLC system.

The above objective is divided into three goals which are essential in clinically supporting MLC systems:

1. To develop and implement an algorithm for the geometric optimization of MLC conformation based on an arbitrary contour shape (Chapter 2).
2. To develop and implement a user interface module of the MLC into a radiation therapy treatment planning (RTTP) system based on a beam's eye view (BEV) display (Chapter 2).
3. To develop an algorithm to determine the change of in-air output factor for shaped fields (Chapters 3 - 6).

CHAPTER 2

DEVELOPMENT OF AN MLC MODULE FOR A TREATMENT PLANNING SYSTEM

Introduction

An MLC system offers a state-of-the-art method for field shaping in radiation therapy. The advantage of using an MLC is that since the field shaping is performed using leaves, the fabrication of custom blocks is no longer needed. This increases the treatment delivery efficiency because multiple fields can be treated in a short time without reentering the treatment room. It also eliminates all problems associated with heavy blocks, alterations, remodeling and remounting. The most important advantage of this technology lies in its potential for use in the delivery of 3-D conformal therapy and intensity modulated radiation therapy.

An issue that discourages some clinicians from accepting MLCs more readily is the 'zigzag' approximation to the shape of the target volume with an MLC system because of the finite leaf edge dimension compared with the smooth conformation using shaped blocks. This inherent drawback of MLCs introduces some change in the concept of beam collimation; that is, an MLC does not necessarily coincide with the target contour prescribed by a physician. Given the geometrical constraints of the setup, it is only possible to achieve an 'optimal' field fit with the MLC system. The optimization criteria must be incorporated into the planning process as efficiently as possible. Manual placement of all leaves (52 or 80 leaves maximum) that define an MLC portal can be

unacceptably time consuming. Therefore, a facility that automatically derives optimized MLC leaf positions from a prescribed target contour and uses this information for a subsequent treatment plan is necessary.

Methods and Materials

Geometric Optimization of MLC Conformation

The MLC system should be completely integrated in the planning process to realize its full potential clinical benefits. The problem that must be solved is to determine the best MLC leaf positions for the optimal target volume conformation. The use of conventional Cerrobend blocks to get tertiary field margins has provided radiation oncologists a means of smoothly matching the edge of collimation with the projection of the irradiation volume. However, when an MLC is used, the collimation occurs in discrete steps. Therefore, it is important to determine optimal placement of each leaf with respect to the field edge. Several treatment machine-dependent characteristics must be made known to determine leaf settings automatically with a computer algorithm, such as the number of leaves, their widths, travel limits, source to MLC distance, and relative leaf travel direction.

In this study, an optimization program was designed to fit a Varian MLC system. Nevertheless, it is flexible in nature and can be adapted to any MLC systems. In the Varian design, the MLC is an add-on device that mounts to the existing clinical accelerator head. A total of 26 pairs of leaves can produce the maximum MLC field size

of $26 \times 40 \text{ cm}^2$ at the isocenter plane. Each leaf can travel up to 16 cm beyond the isocenter with the maximum leaf speed of 1.5 cm/sec.

In the design of the optimization program, three automatic leaf coverage strategies were provided as illustrated in Figure 2-1:

- (a) 1/2 Overblocking : Each leaf end intersects with the prescribed field edge at its midpoint. This is a simple algorithm that sets equal amounts of overblocking and underblocking with regard to each leaf (LoSasso et al. 1993).
- (b) Full overblocking (or zero underblocking): Leaf positions are always inside the field to minimize the irradiation of normal tissue.
- (b) 1/3 Overblocking: Each leaf end intersects with the prescribed field edge at one of the 'one third point' of the leaf end. In this strategy, about 1/3 of the leaf end is inside the field. This strategy is a simplified algorithm of 'variable insertion' done by Zhu et al. (1992) that results in the 50% isodose line always outside the desired field edge.

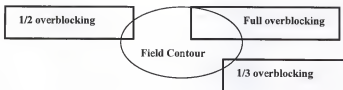


Figure 2-1. Three automatic leaf conformation strategies.

Depending on the shape of the contour, it is often necessary to rotate the collimator or to shift the contour with respect to the beam to get a better fit of leaves with the target contour (e.g., 90° rotation for the diamond shape of contour). Strategies of collimator rotation and contour shift are also provided. In the contour shift option, a contour can be shifted in both the x- and y-direction.

Regardless of the automatic technique used, the MLC aperture shape may not be logical when evaluated by the treatment planner. Sometimes, it is necessary to adjust individual leaves to ensure target coverage in a critical region or to avoid small critical structures, e.g., the optic chiasm, which may be close to a target volume. Therefore, a manual leaf adjustment facility is provided in the BEV. In this option, each leaf can be manually positioned, around a target volume or a critical structure.

User Interface Module

It is desirable to have MLC field shaping algorithm which is incorporated into the RTP system. A stand alone software package is more error prone and time consuming. Therefore, it is necessary to develop and implement an user interface module of the MLC model within an existing RTP system.

There are many commercially available RTP systems. Although the functional characteristics of RTP systems are very similar to each other, each RTP system is different from others in the structure of its programming; thus, an user interface module of the MLC must be compatible with the RTP system used at each hospital. One of the more popular commercial RTP systems is the Radiation Oncology Computer Systems

(ROCS) RTTP system (ROCS 1994) which was installed in the University of Florida's Department of Radiation Oncology in 1994 and has been used as its main RTTP system. In this study, an MLC user interface module which is adaptable to the ROCS RTTP system was developed.

The source program for the user interface module is written in BASIC. Because most modules of the ROCS RTTP system are written in BASIC, this was the programming language of first choice. The following key points were adhered to during the development of this MLC software module:

- a) minimal change of the present source program,
- b) minimal change of the present program structure,
- c) minimal change of the present data library and their format, and
- d) easy adaptation of the new module to the present RTTP system.

Results

A total of 38 subroutines were newly created and 8 present subroutines were revised to develop an MLC optimization and user interface module for the ROCS main RTTP system. The description of each newly generated subroutine is summarized in Table 2-1. The complete source program of the module is contained within Appendix A.

Figure 2-2 shows a flow chart of the module. In the ROCS main module, users enter into the irregular field module. Using the 'field editor' module, users can create irregular fields. Once irregular fields are provided, the 'MLC field editor' module can be

used. In the 'MLC field editor' module, users can create MLC fields using the 'edit field' tool. To perform leaf conformation, MLC geometric optimization strategies are used in the 'edit field' tool. For geometric optimization, 'automatic fit', 'collimator angle selection', 'contour shift', and 'manual fit' strategies are used. Calculation points can be defined after the MLC field is provided using the 'point editing' tool. Once an MLC field is created, users can make the opposite field simply by selecting the 'opposite field' option in the 'MLC field editor' module. The 'export field' option creates an ASCII file for file transfer to the MLC controller computer on the treatment machine.

Conclusion

An MLC geometric optimization and user interface module was developed as part of this research. The module was implemented to the main RTTP system, ROCS (version 5.1.1) and is currently in clinical use. The planning time was significantly reduced by incorporating the MLC module into the main RTTP system.

Table 2-1. Description of subroutines.

MLCINI:	This subroutine specifies MLC dimension and set main variables.
MLCDRAW:	This subroutine draws MLC leaves with leaf position data.
MLCOPT:	This subroutine searches geometrically optimized MLC leaf position.
MANOPTI:	This subroutine enables manual MLC field editing.
LEAFLT:	This subroutine moves leaf to left direction during manual fit.
LEAFUP:	This subroutine selects upper leaf during manual fit.
LEAFRT:	This subroutine moves leaf to left direction during manual fits
LEAFDN:	This subroutine selects lower leaf during manual fit.
REDRAWMLC:	This subroutine redraws MLC leaf changed during manual fit.
NOTELEAF:	This subroutine assigns different color to selected leaf during leaf change in same side.
NOTE2LEAF:	This subroutine moves cursor and assigns different color to selected leaf during leaf change between two different sides.
MLCSETMENU:	This subroutine displays MLC field editor menu.
AUTOFIT:	This subroutine carries out geometric optimization for MLC field automatically.
MANUFIT:	This subroutine carries out geometric optimization for MLC field manually.
MLCOPTUNDER:	This subroutine searches geometrically underblocked MLC leaf position.
MLCOPTOVER:	This subroutine searches geometrically overblocked MLC leaf position.
AUTOUNDER:	This subroutine carries out geometric underblocked optimization for MLC field automatically.
AUTOOVER:	This subroutine carries out geometric overblocked optimization for MLC field automatically.

Table 2-1. -- continued.

CONVERTANG:	This subroutine converts collimator angle in degree to radian and get sine, cosine values.
MLCGETANG:	This subroutine gets collimator angle in degree as user input.
MLCSHIFTX:	This subroutine gets MLC offset in X-dir. as user input.
MLCSHIFTY:	This subroutine gets MLC offset in Y-dir. as user input.
MFLDDATA:	This subroutine gets collimator opening, field outline and calculation point location for MLC field.
SAVEMFLD:	This subroutine prompts the user to save MLC field data. If the user chooses to save the data the MLC data file and the irregular library file are updated.
MFLDDEF:	This subroutine displays an MLC field based on user input. The user selects an MLC field and chooses to edit, load, oppose or export MLC fields.
GETMFLD:	This subroutine gets MLC field data from the file.
IR7:	This subroutine is the MLC field main editing menu. Control is transferred to the appropriate routine based on which function key is pressed.
ISODRW:	This subroutine draws original isocenter before MLC offset
LEAFINI:	This subroutine sets initial values for leaf position.
LEAFRETRIV:	This subroutine sets existing MLC field.
GETIFLD2:	This subroutine gets irregular field data from the file.
SAVEIFLD2:	This subroutine prompts the user to save irregular field data. If the user chooses to save the data the irregular data file and the irregular library file are updated.
GETMFLD2:	This subroutine gets MLC field data from the file.
SAVEMFLD2:	This subroutine prompts the user to save MLC field data. If the user chooses to save the data the MLC data file and the irregular library file are updated.

Table 2-1. -- continued.

MLCOPPOSE:	This subroutine creates opposed MLC field. Opposed block field is generated at the same time.
MLCEXPORTV:	This subroutine creates MLC field data file to be exported for Varian type. Exported file can be directly used by Varian MLC software, "SHAPER".
MLCSELECT:	This subroutine prompts the user to select MLC type.
MLC1PAGE:	This subroutine displays one page of beam information for MLC field.

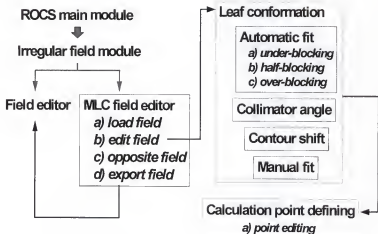


Figure 2-2. Outline of MLC module.

CHAPTER 3

A STUDY OF THE EQUIVALENT FIELD CONCEPT FOR THE HEAD SCATTER FACTOR

Introduction

In general, the *equivalent field* is defined as a field having the same central axis depth-dose characteristics as the given field (Jones 1949, Day 1950). The relationship between equivalent fields is based on integration of the phantom scatter parameter for shaped fields. Therefore, a field is determined that produces the same ratio of phantom scatter to primary dose on the central axis (Day & Aird 1983). It has been generally assumed that the radiation output has two scatter components, S_c and S_p ; in convention, S_c is referred to as the collimator scatter factor, which is characterized by the X and Y jaw collimator openings, and S_p accounts for phantom scatter, which depends on the area of the irradiated phantom. Although S_c is called the collimator scatter factor, S_c accounts for both the monitor backscatter contribution and the head scatter contribution to the in-air output. The monitor backscatter factor (Lam et al. 1996, Ahnesjö et al. 1992, Patterson & Shragge 1981, Luxton & Astrahan 1988, Moyer 1978, Higgins et al. 1989, Kubo & Lo 1989, Kubo 1989, Duzenli et al. 1993) can be separated from S_c . The term, 'head scatter factor' is limited to the contribution of head scatter in this present study. For nonstandard fields such as rectangular and irregular fields, conventionally, S_p is obtained through the equivalent field relation, and the equivalent field relation for phantom scatter is well

established (Day & Aird 1983, Bjärngård & Siddon 1982). The equivalent field method has also been applied for determination of the scatter contribution to the in-air dose from any scattering structure, such as the flattening filter. The stipulation is that the equivalent field contributes the same amount of scatter radiation on the central axis as the collimator-set field. The relationship between equivalent fields for head scatter is based on integrating the head scatter parameter of the shaped field and finding the field that produces the same ratio of head scatter to primary dose on the central axis. The head scatter characteristics are not the same as the phantom scatter characteristics. Therefore, it is necessary to establish the equivalent field relationship for head scatter separately from that for phantom scatter.

When a scattering structure is located above the collimator, such as the flattening filter or an internal wedge, the amount of scatter radiation that can reach a detector is related to the configuration of the field at the source plane as seen from the detector, that is, the detector's eye view (DEV) field (Lam et al. 1996, Ahnesjö 1994). When head scatter factor is parametrized at the flattening filter (or the source) plane (Lam et al. 1996) or the field mapping method (see Chapter 4) is used, it is imperative to assess the equivalent field relationship at the source (or flattening filter) plane. Lam et al. (1996) empirically showed that the formula of the area-to-perimeter ratio for the equivalent square of a rectangular field for phantom scatter (Sterling et al. 1964, Worthley 1966) is also valid for head scatter at the source plane and this relationship was successfully applied to obtain a modified equivalent square formula at the detector plane through the field mapping method. For an irregular field, conventionally, the head scatter factor is

approximated by that of the rectangular field determined by the secondary collimators.

Although the conventional method gives a good approximation in most clinical cases, the difference of head scatter factor between a rectangular field and an irregular field can be significant when the irregular field is much smaller than the rectangular field such as mantle fields and fields in intensity modulation therapy. Furthermore, when an irregular field is created by Philips type MLCs, which replace the upper set of secondary collimators, the conventional method can not be used (Palta et al. 1996). In these cases, Clarkson integration (Clarkson 1941) can be applied for a better estimation of head scatter factor for irregular fields (Boyer 1996). To use Clarkson integration, it is required to evaluate the equivalent field relationship between a circular field and a square field.

The use of Clarkson integration can also be expanded for the prediction of scatter contribution from both the beam modifier (e.g., wedge) and the tertiary collimator (e.g., Cerrobend block and Varian type MLC) when it is needed to independently deal with wedge scatter or tertiary collimator scatter. The amount of scattered radiation from a wedge depends on the area of the wedge that intercepts the radiation coming downstream through the treatment head. If a wedge is located above the collimator jaws like that in a Philips machine, the detector's eye view field at the source plane can be used for both head scatter and wedge scatter. However, when the wedge is located underneath the secondary collimator like that in a Varian machine equipped with an MLC, the field size for the wedge scatter contribution is different from the field size for the head scatter contribution. Whereas the head scatter contribution is determined by the field seen by the detector's eye view, the wedge scatter contribution depends on the field size projected at

the detector plane. Therefore, in this case, wedge scatter should be dealt with separately from head scatter. Tertiary collimator scatter contribution may also be separately treated when the amount of scatter is not negligible. For both wedge and tertiary collimator scatter, the amount of scatter radiation that can reach a detector is related to the configuration of the field projected at the detector plane. Therefore, in these cases, the equivalent field relationship is obtained at the detector plane.

In this chapter, the equivalent field relationship of square and circular fields was provided at the source plane for the head scatter factor. The fact that the area-to-perimeter ratio of the equivalent square of a rectangular field for phantom scatter is also valid for head scatter at the source plane (Lam et al. 1996) was analytically investigated. The equivalent field relationships for wedge scatter and tertiary collimator scatter were assessed at the detector plane.

Methods and Materials

Equivalent Field for Head Scatter Factor

The photon energy fluence equation at a detector point may be defined as

$$\begin{aligned}
 \Psi &= \Psi_p + \Psi_s \\
 &= \Psi_p \left(1 + \frac{\Psi_s}{\Psi_p} \right) \\
 &= \Psi_p (1 + SPR_h),
 \end{aligned} \tag{3.1}$$

where Ψ_p is the energy fluence due to primary photons, Ψ_s is the energy fluence due to scatter photons from the head, and SPR_h is the ratio of scatter fluence originating in head to primary fluence. Assuming that dose is linearly proportional to energy fluence in megavoltage photon beam, the equivalent field can be defined as the field that gives the same scatter-to-primary ratio, SPR_{eq} , as the collimator-defined field. The SPR_h of any arbitrary shaped field is the integration of the differential scatter-to-primary ratio function over the whole field,

$$SPR_h = \iint \frac{dSPR_h}{dA} dA . \quad (3.2)$$

Several models have appeared in the literature that accurately describe the scatter photon energy fluence distribution that emanates from the head such as uniform (Ahnesjö et al. 1992), triangular (Ahnesjö 1994), Gaussian (Dunscombe & Nieminen 1992), a combination of several functions (Yu & Sloboda 1993), and experimentally determined distribution functions (Jaffray et al. 1993). Ahnesjö (1994) concentrated on scattered photons from the flattening filter and calculated the differential scatter-to-primary ratio of flattening filter scatter, $dSPR_f/dA$, according to the radius from the central axis, using the first scatter approximation. Ahnesjö's work showed that $dSPR_f/dA$ is well described by either Gaussian or triangular function (Ahnesjö 1994). Since the dominant contributor of head scatter is the flattening filter (Kase & Svensson 1986), we assume that the equivalent field relationship for head scatter primarily depends on the characteristics of scatter from the flattening filter. We can replace SPR_h with SPR_f , the scatter-to-primary ratio of scatter from the flattening filter, in Eq. (3.2):

$$SPR_f = \iint \frac{dSPR_f}{dA} dA . \quad (3.3)$$

Based on Ahnesjö's study (Ahnesjö 1994), it is assumed that the differential scatter-to-primary ratio of flattening filter scatter, $dSPR_f/dA$, decreases linearly according to the radius within the physical radius of the flattening filter, that is,

$$\frac{dSPR_f}{dA} = b - ar , \quad (3.4)$$

where a and b are coefficients dependent on the photon beam energy and the shape and material of the flattening filter. By substituting Eq. (3.4) into Eq. (3.3), the scatter-to-primary ratio for scatter from the flattening filter for any field is given by

$$SPR_f = \iint (b - ar) dA . \quad (3.5)$$

It has been reported that the contribution of backscatter into the monitor chamber has a significant influence on the dependence of in-air output on secondary collimator settings (Lam et al. 1996, Ahnesjö et al. 1992, Patterson & Shragge 1981, Luxton & Astrahan 1988, Moyer 1978, Higgins et al. 1989, Kubo & Lo 1989, Kubo 1989, Duzenli et al. 1993). However, monitor backscatter affects both primary and scatter photons in the same way, thus, the shape of the differential scatter-to-primary ratio function, $\frac{dSPR_f}{dA}$ does not change. That is, the equivalent field relationship is not affected by the monitor backscatter at the source plane if monitor backscatter factor is separated from collimator scatter factor.

Equivalent square of a circular field. For a circular field with radius R , the result of the integration (Eq. [3.5]) is

$$\begin{aligned}
SPR_f(cir) &= b\pi R^2 - a \frac{2}{3} \pi R^3 \\
&= 3.142bR^2 - 2.094aR^3 .
\end{aligned} \tag{3.6}$$

For a square field with a side of $s=2\sigma$, the result of the integration (Eq. [3.5]) is

$$SPR_f(sq) = 4b\sigma^2 - 3.061a\sigma^3 . \tag{3.7}$$

From Equations (3.6) and (3.7),

$$4b\sigma^2 - 3.061a\sigma^3 = 3.142bR^2 - 2.094aR^3 . \tag{3.8}$$

By dividing both sides with bR^3 and using $(a/b) = (1/R_{max})$ in Eq. (3.8), we can eliminate the coefficients, a and b , that is, we get

$$4\left(\frac{\sigma}{R}\right)^2 \left(\frac{1}{R}\right) - 3.061\left(\frac{1}{R_{max}}\right)\left(\frac{\sigma}{R}\right)^3 = 3.142\left(\frac{1}{R}\right) - 2.094\left(\frac{1}{R_{max}}\right) , \tag{3.9}$$

where R_{max} is the maximum radius of the flattening filter. Now, multiply Eq. (3.9) by R and rearrange to obtain

$$\left(4\alpha^2 - 3.142\right) + \left(2.094 - 3.061\alpha^3\right)\left(\frac{R}{R_{max}}\right) = 0 , \tag{3.10}$$

where $\alpha = (\sigma / R)$. Equation (3.10) indicates that α is dependent on the radius R . For a very small field, that is, when $R \rightarrow 0$, $\alpha = 0.886$ is obtained. Note that this is the same result that would be obtained by simply equating the area of the circle to the area of the square. Whereas Eq. (3.6) is valid within the maximum radius of the flattening filter, R_{max} , the valid range of Eq. (3.7) is given by one half the side of the largest square which can be inscribed within the circle of radius R_{max} , that is, $\sigma_{max} = R_{max} / \sqrt{2}$. Therefore, the safe limit of R , which guarantees the validity of Eq. (3.10), is given by $R_{lim} = R_{max} / \sqrt{2}$. With

$R = R_{\text{eq}}$, Eq. (3.10) gives $\alpha \approx 0.9$. Therefore, we can find the approximate range within which the equivalent square field exists for the given circular field,

$$0.886 R \leq \sigma \leq 0.9 R, \quad (3.11)$$

where R = the radius of the circle and σ = one half of the side of the square. For convenience, we may use one value of $\sigma = 0.9 R$. Equation (3.11) is obtained within the dimension of flattening filter. However, it is considered that it can be used even when a field at the flattening filter plane (or source plane) is larger than the dimension of the flattening filter because the amount of scatter outside the flattening filter is relatively small and slightly varies according to the radius. This fact is discussed in detail in discussion section.

In-air output factors of circular fields and square fields were measured with a cylindrical acrylic miniphantom as described by van Gasteren et al. (1991). The cylindrical phantom is 3.8 cm in diameter and 15 cm long. Measurements were taken on a Varian 2100C with 8 MV and 18 MV photon beams. A shonka plastic 0.1 cc ionization chamber was inserted in the miniphantom with its center located at 5 cm for 8 MV or 10 cm for 20 MV from the front surface and 100 cm from the source. Both circular fields (radius, $r = 2.2, 3.3, 5.6, 7.8$, and 10 cm at the source plane) and square fields (side, $s = 4, 6, 10, 14$, and 18 cm at the source plane) were created by an MLC. Each square field corresponds to the equivalent square field of each circular field. During the measurements, secondary collimators were set as 40 x 40 to eliminate the relative effect of monitor backscatter.

Equivalent square of a rectangular field. For a rectangular field of dimensions $L \times W$, the integration (Eq. [3.5]) gives

$$\begin{aligned} SPR_f(rec) &= bLW - a \frac{1}{12} \left\{ 2LWD + L^3 \ln \tan\left(\frac{\pi}{4} + \frac{\phi}{2}\right) + W^3 \ln \tan\left(\frac{\pi}{2} - \frac{\phi}{2}\right) \right\} \\ &= bLW - a \frac{1}{12} \left\{ 2LWD + L^3 \ln \left[\frac{D+W-L}{L+W-D} \right] + W^3 \ln \left[\frac{D+L}{W} \right] \right\}, \end{aligned} \quad (3.12)$$

where D is the length of the diagonal of the rectangle and $\phi = \tan^{-1} W / L$. In Equations (3.7) and (3.12), it is not easy to obtain a simple equivalent square correlation for a rectangular field.

Lam et al. (1996) obtained good agreements between the head scatter factors of square fields and those of rectangular fields by using the area-to-perimeter ratio formula as an equivalent square formula at the flattening filter plane for 6 MV and 15 MV photon beams of Varian 2100C. We have calculated $1 + SPR_f$ values, using Eq. (3.12) for different $L \times W$ rectangular fields and Eq. (3.7) for square fields of $s = 2LW / (L + W)$ and compared each other.

Equivalent Field for Wedge and Tertiary Collimator Scatter Factor

For both wedge and tertiary collimator such as a conventional Cerrobend block and Varian-type MLC, we can assume

$$\frac{dSPR}{dA} = a. \quad (3.13)$$

With Eq. (3.13), it is trivial to calculate an equivalent square field,

$$\sigma = 0.886 R, \quad \text{for a circular field with radius } R, \quad (3.14a)$$

and

$$s = 2\sigma = \sqrt{LW}, \quad \text{for a rectangular field of } L \times W. \quad (3.14b)$$

For convenience, we can use $\sigma = 0.9 R$ for a circular field without significant error.

To evaluate the validity of the assumption, Eq. (3.13), scatter contribution from tertiary collimator (Cerrobend block and Varian MLC) was measured according to the irradiated area with the same mini-phantom as described in the section *Equivalent square of a circular field*. A set of measurements were made underneath a solid piece made out of the same material as the tertiary collimator material (Cerrobend or MLC) with field sizes ranging from 4×4 to $20 \times 20 \text{ cm}^2$ at the detector plane. The thickness of Cerrobend block was 7.5 cm. The data were extrapolated to $0 \times 0 \text{ cm}^2$ field. The in-air output of $(0,0)$ field multiplied by $S_c(X,Y)/S_c(0,0)$ was subtracted from in-air output for each field size, (X,Y) . The remaining in-air output of each field is only due to the scatter radiation from tertiary collimator material. Scatter contribution from a 45° wedge was also measured. When Clarkson integration is carried out on wedge scatter for an irregular field, the assumption Eq. (3.13) is theoretically not correct, except in the case of a symmetric field, because of the change in wedge thickness. However, if the difference in in-air output between asymmetric fields is not significant, we may use that assumption without significant error. We measured in-air outputs for a pair of asymmetric wedged fields (see Figure 3-1). One field contains the most thin part and very little of the thick part of the wedge, and the other is reverse (e.g., field sizes $[X1=2.5, X2=10, Y1=10, Y2=10]$ and $[X1=10, X2=2.5, Y1=10, Y2=10]$, in which the X axis was parallel to the axis of slope of

the wedge). The contribution of unattenuated photons to in-air output is same for both fields because the detector is located at the isocenter. The only difference comes from wedge scatter contributions.

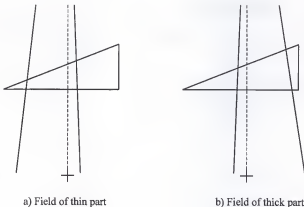


Figure 3-1. Description of a set of asymmetric wedged fields. The contribution of unattenuated photons to in-air output is same for both fields. However, the wedge scatter contribution is different.

Results

Equivalent Field for Head Scatter Factor

Equivalent square of a circular field. The measured in-air output factors of an 8 MV and 18 MV photon beams of Varian 2100C are shown in Figures 3-2 and 3-3, respectively. In Figures 3-2 and 3-3, the in-air output is normalized to that of 10 x 10 MLC field at the source plane. Circular fields are converted to equivalent square fields using the equivalent

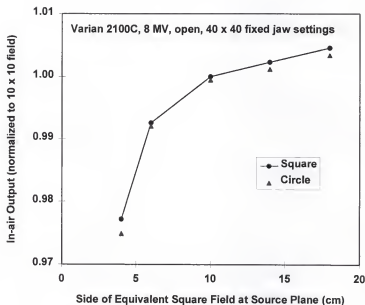


Figure 3-2. In-air output factor as a function of a circular field at the source plane for the 8 MV photon beam of a Varian 2100C. Fields were made by an MLC system. During the measurements, secondary collimators were fixed at 40 x 40 cm². Data are plotted according to the side of the equivalent square obtained by $\sigma = 0.9 R$. Data for square fields are also plotted for comparison.

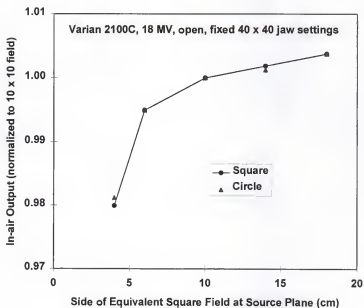


Figure 3-3. In-air output factor as a function of a circular field at the source plane for the 18 MV photon beam of a Varian 2100C. Data are plotted according to the side of the equivalent square obtained by $\sigma = 0.9R$.

field relation, $\sigma = 0.9R$. The difference of in-air output factors between circular field and square field is within 0.2 % for both 8 MV and 18 MV beams. Measured in-air output accounts for not only head scatter but also the effect of backscatter into the monitor chamber and forward scatter to the detector from the MLC. However, since the field shapes of circular fields and square fields are very close, it is considered that the amounts of scatters (both backscatter to the monitor chamber and forward scatter to the detector) of both fields are almost the same. Therefore, the difference of in-air output factors between two fields (circular and square fields) indicates the difference of head scatter factors. In a Varian 2100C, the radius of flattening filter is 3.6 cm at the source plane. That is, two fields ($r = 2.2$ and 3.3 cm) are smaller than the flattening filter and others are larger. Measurements show that the equivalent field relation, $\sigma = 0.9R$ is also valid even when a field is larger than the flattening filter.

Equivalent square of a rectangular field. Values of the percentage differences between values for $1+SPR_f$ for rectangular and square fields are plotted in Figure 3-4 according to the elongation ratio. In Figure 3-4, the percentage difference was calculated as

$$100\{[1+SPR_f(\text{eq. square})] - [1+SPR_f(\text{rectangle})]\} / [1+SPR_f(\text{rectangle})] . \quad (3.14)$$

The coefficients a and b in Eq. (3.4) are obtained from Ahnesjö's work (Ahnesjö 1994).

From Figure 3-4, it can be noted that the amount of difference is dependent on the beam energy and the material and size of flattening filter. The most dominant factor is the material of the flattening filter. Whereas an aluminum flattening filter shows a larger difference (maximum -2.9 % with an elongation ratio of 10), a tungsten filter shows a smaller difference (maximum -1.4 % with an elongation ratio of 10). We can also see that

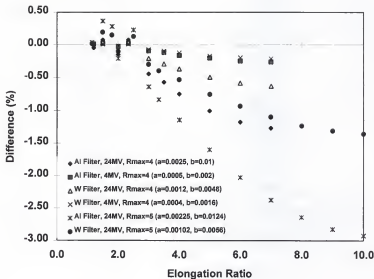


Figure 3-4. Difference (%) of $1+SPR_f$ between a rectangular field and the equivalent square field according to the elongation ratio. The equivalent field is determined by the area-to-perimeter relation. The difference (%) is given by $100[\{1+SPR_f(\text{eq. square})\} - \{1+SPR_f(\text{rectangle})\}] / \{1+SPR_f(\text{rectangle})\}$. Data for determination of $dSPR_f/dA$ are obtained from Ahnesjö's work (Ahnesjö 1994). The elongation ratio is given by [length of long side] / [length of short side] of the rectangular field.

a smaller flattening filter ($R_{max} = 4$ cm) gives less difference (-1.27 % for an aluminum filter with an elongation ratio of 7 and -0.63 % for a tungsten filter with an elongation ratio of 7) than does a larger filter (for $R_{max} = 5$ cm, -2.38 % for an aluminum filter with an elongation ratio of 7 and -1.10 % for a tungsten filter with an elongation ratio of 7) at the same elongation ratio. In principle, the amount of difference is dependent on the coefficient, a . The stiffer slope causes the larger difference. Lower Z material, higher energy beam, and larger radius of flattening filter require a thicker flattening filter which causes stiffer slope of scatter function. Since R_{max} is the physical radius of a flattening filter at 15 cm downstream from the source, the maximum radial field size at 100 cm SSD becomes $6.67R_{max}$. That is, for $R_{max} = 4$ cm, the radius of the field at 100 cm is 26.7 cm (diameter $d = 53.3$ cm). Considering the fact that most linear accelerators allow a maximum 40×40 cm² field size and also that a high Z material is preferred as a flattening filter, it appears Figure 3-4 supports the fact demonstrated by Lam et al. (1996) that the formula for the area-to-perimeter ratio can also be used as the equivalent field formula for head scatter at the source plane.

Equivalent Field for Wedge and Tertiary Collimator Scatter Factor

Measured scatter contributions from the tertiary collimator (Cerrobend block and Varian MLC) of an 8 MV photon beam of Varian 2100C are shown in Figure 3-5. Figure 3-5 shows that the behavior of tertiary collimator scatter is very close to a linearly increasing function according to the irradiated area. Therefore, it is considered that Eq. (3.13) is a reasonable assumption. A similar result is obtained for a wedge (Figure 3-6).

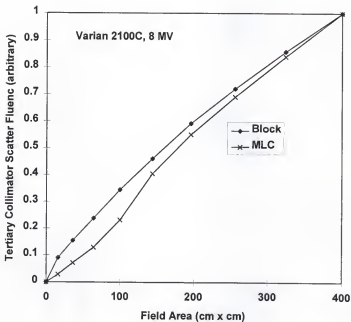


Figure 3-5. Tertiary collimator scatter contribution as a function of field area of solid tertiary collimator material for the 8 MV photon beam of a Varian 2100C. Data are plotted according to the irradiated area projected to the detector plane.

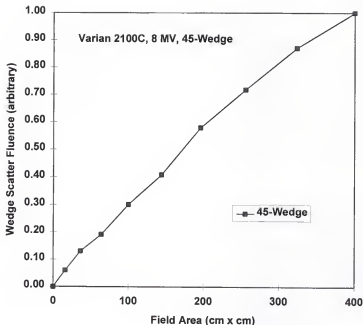


Figure 3-6. Wedge scatter contribution as a function of field area of 45° wedge for the 8 MV photon beam of a Varian 2100C. Data are plotted according to the irradiated area projected to the detector plane.

The measured in-air outputs for a pair of asymmetric wedged fields are summarized in Table 3-1, where we can see that the difference is less than 1%. The contribution of unattenuated photon to in-air output is same for both fields because the detector is located at the isocenter. The only difference comes from the wedge scatter contribution. Considering that most practical fields are closer to symmetric than those studied, we can expect that the differences will become smaller in most clinical cases. Therefore, we can use Eq. (3.13) without compromising accuracy.

Discussion

In the derivation of equivalent field relationship, SPR_h is replaced with SPR_f and it is assumed SPR_f is a linear function. There are two concerns with this approach. The one is that SPR_h can be described better as either a Gaussian (Dunscombe & Nieminen 1992) or polynomial (Yu & Sloboda 1993) function. The other is that SPR_f is restricted within the physical dimensions of the flattening filter. However, the approach is very reasonable for circular fields. For a circular field with radius of R , the equivalent square field exists within the range of $0.71R < \sigma < R$. The circle which can inscribe the square $\sigma = R$ is $r = 1.41R$. Thus, the range we are interested in for the integration of SPR function to obtain the equivalent square is only $0.71R < r < 1.41R$. Physically we are not interested in how SPR varies both inside $0.71R$ and outside $1.41R$. If SPR is close to a linear function between $r = 0.71R$ and $r = 1.41R$, our assumption can be applied and this is the most cases even outside the flattening filter. For rectangular fields, these concerns still remain,

Table 3-1. Comparison of in-air output factors between pairs of asymmetric wedged fields for the 8 MV photon beam of a Varian 2100C. The contribution of unattenuated photon to in-air output is same for both fields. However, wedge scatter contribution is different. Data are normalized to the in-air output of the field of thin part.

Wedge Angle	In-air Output Factor (normalized to field of thin part)			
	X1 = 10, X2 = 2.5, Thin Part		X1 = 2.5, X2 = 10, Thick Part	
	Y = 5	Y = 20	Y = 5	Y = 20
15	1.000	1.000	1.002	1.005
30	1.000	1.000	1.002	1.007
45	1.000	1.000	1.002	1.007
	X1 = 7.5, X2 = 2.5, Thin Part		X1 = 2.5, X2 = 7.5, Thick Part	
60	1.000	1.000	1.001	1.004

especially for highly elongated fields. Therefore, Eq. (3.12) and the analysis results, Figure 3-4, are restricted within the physical dimensions of the flattening filter (e.g., $D = 3.55$ cm at the source plane for Varian 2100C).

In an irregular field, scatter contribution from a tertiary collimator depends not only on the irradiated area perpendicular to the axis, but also on the irradiated area of side wall on the field edge. However, the scatter contribution from side wall is not included in the derivation of Eq. (3.14). This effect should be independently treated because it is dependent of contour shape.

Conclusion

Equivalent field relationships for the head scatter factor at the source plane were analyzed. A relationship of $\sigma / R \cong 0.9$ was obtained for a circular field, where σ is one half the side length of the equivalent square and R is the radius of the circular field. The fact that the formula for the area-to-perimeter ratio of the equivalent square of a rectangular field for phantom scatter is also valid for head scatter at the source plane in most clinical linear accelerators was analytically investigated. The equivalent field relationships for wedge and tertiary collimator scatter were also studied. The relationships of $\sigma = 0.886 R$ (or 0.9 for convenience) for a circular field and $\sigma = \sqrt{LW} / 2$ for a rectangular field were obtained. These relationships can be used in the calculation of in-air output factors for irregular fields in clinical applications.

CHAPTER 4

AN EQUIVALENT SQUARE FIELD FORMULA FOR DETERMINING HEAD SCATTER FACTORS OF RECTANGULAR FIELDS

Introduction

The head scatter factor (or collimator scatter factor) accounts for the change in scattered radiation with collimator setting that reaches the point of measurement on the central axis in high energy x-ray beams. Conventionally, the head scatter factor is expressed as

$$H(X_D, Y_D) = D(X_D, Y_D) / D(X_D=10, Y_D=10), \quad (4.1)$$

where $D(X_D, Y_D)$ is the dose in air on the central axis at the reference plane (which we call the *detector plane* hereafter), which is usually the isocenter, and X_D, Y_D are the field sizes determined by the lower and upper collimator jaws, respectively, at the detector plane.

The collimator setting for the reference field size is 10 cm for both x and y sets of jaws.

For a wedged field, the change in scattered radiation with collimator setting depends not only on the head scatter but also on the wedge scatter. Thus, we will use a different terminology, 'wedge-head scatter factor' for wedged field.

Head (or wedge-head) scatter factor, H is often measured as a function of square field size at the isocenter. To account for H of a rectangular field, usually the well established equivalent square relations are used, either in the form of table (Day & Aird 1983) or the area-to-perimeter ratio formula (Sterling et al. 1964). These formulae give an

estimate of the effect of field elongation only. An inherent assumption is that the head (or wedge-head) scatter factors for two different rectangular fields, $L \times W$ (i.e., $X_D=L$, $Y_D=W$) and $W \times L$ (i.e., $X_D=W$, $Y_D=L$), are the same. In reality, $H(X_D, Y_D)$ is different from $H(Y_D, X_D)$ by 2 ~ 3% for open fields (Moyer 1978, Kase & Svensson 1986, Tatcher & Bjärngård 1993) and 3 ~ 4% for wedged fields (Tatcher & Bjärngård 1993) between two different rectangular fields, $L \times W$ and $W \times L$. This collimator exchange effect has been discussed extensively in the literature (Vadash & Bjärngård 1993, Moyer 1978, Kase & Svensson 1986, Tatcher & Bjärngård 1993, Lam et al. 1996). Vadash and Bjärngård (1993) obtained an empirical formula to account for this exchange effect for a Philips machine. Yu et al. (1995) obtained the same empirical formula for a Varian machine. Lam et al. (1996) suggested parametrization with the equivalent square at the flattening filter to account for this effect. Ahnesjö (1994) modeled the energy fluence of scattered photons from the flattening filter by approximating the fluence to be proportional to the solid angle of the filter seen from the isocenter. All of these recent publications provide methods to calculate change in head scatter as a function of the field size; these methods explicitly account for the upper and lower collimator settings.

Another simple equivalent square formula that accounts for the collimator exchange effect was provided. The formula was derived by a method that will henceforth be called the *field mapping method*. In the field mapping method, a field that is defined in the source plane by back-projection from the point of measurement (i.e., the detector's eye view) is mapped back into the detector plane by an equivalent field relationship. Therefore, this method retains parametrization at the detector plane (measurement point).

No new data are required to implement the method clinically. The field size dependence of head (or wedge-head) scatter that is measured for a range of square field sizes is sufficient to implement this method.

Theory

The head scatter factor primarily depends on scattered radiation called *extrafocal radiation* (Jaffray et al. 1993) above the field-defining collimators (e.g., the flattening filter). Therefore, head scatter accounts for not only the primary but also the scattered radiation. The magnitude of the scattered radiation from extrafocal sources is accurately determined by the projected area in the source plane from the detector's eye view rather than the conventional field area at the detector plane (Lam et al. 1996, Ahnesjö 1994). Because of the different positions of the lower and upper collimator jaws, projected field sizes at the source plane as determined by the detector's eye view are different for $L \times W$ and $W \times L$ rectangular fields. The projected field in the source plane as defined by the detector's eye view is illustrated in Figure 4-1, where X_D , Y_D are the field sizes determined by the lower (or X) and upper (or Y) collimator jaws, respectively, at the detector plane; X_S , Y_S are the field sizes determined by the X and Y collimator jaws at the source plane through the detector's eye view; l_{1x} , l_{1y} are the distances from the source plane to the top of the X and Y collimators, respectively; and l_{2x} , l_{2y} are the distances from the detector plane to the top of the X and Y collimators. Based on simple divergent

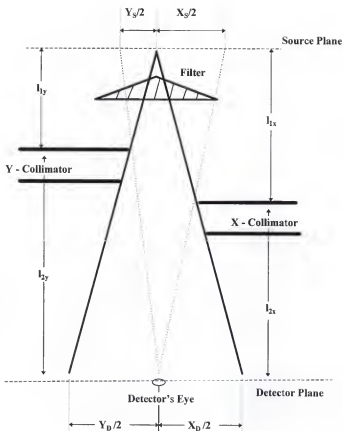


Figure 4-1. Schematic diagram showing the geometric relationship between the detector and the collimator jaws. Also shown are field sizes projected in the source plane and detector plane.

geometry, we can define the field conversion factors from detector to source plane, k_x for X and k_y for Y side, as

$$k_x = l_{1x}/l_{2x}, \quad (4.2)$$

$$k_y = l_{1y}/l_{2y}. \quad (4.3)$$

Note that for most medical linear accelerators, k_x and k_y are less than one. The field size at the source plane, X_S and Y_S becomes

$$X_S = k_x X_D, \quad (4.4)$$

$$Y_S = k_y Y_D. \quad (4.5)$$

Using the area-to-perimeter ratio formula of the equivalent square at the source plane (Lam et al. 1996), we can obtain the equivalent square at the source plane, S_S^{eq} :

$$S_S^{eq} = 2X_S Y_S / (X_S + Y_S). \quad (4.6)$$

Since most dosimetric data are obtained for square fields at the detector plane, it is necessary to find an equivalent square at the detector plane, S_D^{eq} , that gives the same head scatter factor as S_S^{eq} . If we convert the square field, S_D^{eq} , to the source plane, it becomes a rectangular field, $k_x S_D^{eq} \times k_y S_D^{eq}$. If we let $S_S^{eq'}$ be the equivalent square at the source plane for this field, then

$$S_S^{eq'} = 2k_x S_D^{eq} k_y S_D^{eq} / (k_x S_D^{eq} + k_y S_D^{eq}). \quad (4.7)$$

Since $S_S^{eq'}$ should match S_S^{eq} , we obtain

$$S_D^{eq} = \{(k_x + k_y)/2k_x k_y\} S_S^{eq}. \quad (4.8)$$

From Eq. (4.8) and Eq. (4.6), we obtain a modified equivalent square formula,

$$S_D^{eq} = (1 + k) X_D Y_D / (k X_D + Y_D), \quad (4.9)$$

where k is a geometrical weighting factor, defined as:

$$k = k_x/k_y = (l_{1x}/l_{2x})(l_{2y}/l_{1y}) . \quad (4.10)$$

Equation (4.9) provides an equivalent square, which is based on a rectangular field, $X_D \times Y_D$, projected in the detector plane, and the geometric weighting factor, which is accelerator-dependent.

Methods and Materials

Head (or wedge-head) scatter factors of rectangular fields were measured with a cylindrical acrylic miniphantom as described by van Gasteren et al. (1991). The cylindrical phantom is 3.8 cm in diameter and 15 cm long. Measurements were taken on a Varian 2100C with an 8 MV photon beam and a Philips SL25 with a 20 MV photon beam for both open and wedged fields. A shonka plastic 0.1 cc ionization chamber was inserted in the miniphantom with its center located at 5 cm for 8 MV or 10 cm for 20 MV from the front surface and 100 cm from the source. Two independent sets of data were taken. The first set of measurements was taken with the X (lower) collimator jaws fixed while the Y (upper) jaws were varied. In the second set of measurements, the Y collimators were fixed and the X collimators were varied. Collimators were varied from 30×4 to $30 \times 30 \text{ cm}^2$ for the open fields. For wedged fields, collimators were varied from 20×4 to $20 \times 20 \text{ cm}^2$ with a 45° wedge (external wedge) for an 8 MV (Varian 2100C) and from 30×4 to $30 \times 30 \text{ cm}^2$ with a 60° wedge (internal wedge) for a 20 MV (Philips SL25) photon beam. The wedge gradient was always orthogonal to the long axis of the chamber. The data also were measured for a range of square field sizes projected at

the isocenter. Special attention was paid to the position of the chamber on the central axis for measurements with a wedge. Reversing the wedge did not change the measured readings by more than 0.4%.

Results

The measured head scatter factors of an 8 MV photon beam of Varian 2100C normalized to a $10 \times 10 \text{ cm}^2$ field size are shown in Figure 4-2. Figure 4-3 shows the measured wedge-head scatter factors of 45° wedged fields for 8 MV photon beam of Varian 2100C. The rectangular fields are plotted according to the side of the equivalent square field obtained by Sterling's area-to-perimeter relationship (Sterling et al. 1964). The same data are plotted in Figures 4-4 and 4-5 for open and wedged fields but according to the side of the square field obtained by the modified equivalent square formalism presented in Equation (4.9) with the calculated geometric weighting factor, $k = 1.5$, for a Varian 2100C. The collimator exchange effects are obvious in Figures 4-1 and 4-2. The magnitude of the difference in output caused by this effect ranges from 0.2% to 2.5% for both open and wedged fields. The maximum difference is for the most elongated fields. The modified equivalent square formalism provides output with a difference of less than 1% for open fields and less than 0.5% for wedged fields.

Similar results were obtained with the 20 MV photon beam. Head and wedge-head scatter factors are shown in Figure 4-6 and Figure 4-7, respectively, according to the side of the equivalent square field obtained by Sterling's area-to-perimeter relationship

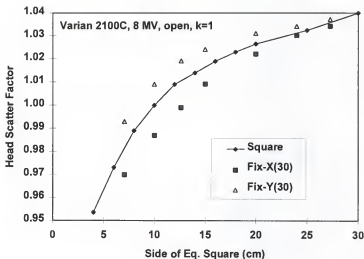


Figure 4-2. Head scatter factor as a function of a rectangular open field for the 8 MV photon beam of a Varian 2100C. During these measurements, one set of collimator jaws was fixed and the other set of collimator jaws was changed symmetrically. The field size varied from 30×4 to $30 \times 30 \text{ cm}^2$. Data are plotted according to the side of the equivalent square obtained by the conventional area-to-perimeter relation.

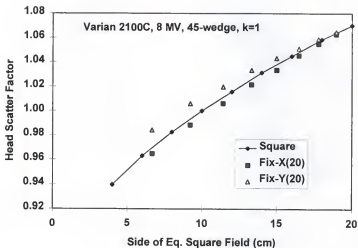


Figure 4-3. Wedge-head scatter factor as a function of a rectangular 45° wedged field for the 8 MV photon beam of a Varian 2100C.

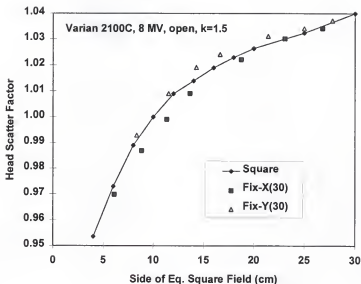


Figure 4-4. Head scatter factor as a function of a rectangular open field for the 8 MV photon beam of a Varian 2100C. Data are plotted according to the side of the equivalent square obtained by Eq. (4.9) with $k = 1.5$.

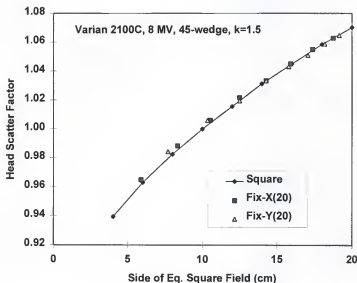


Figure 4-5. Wedge-head scatter factor as a function of a rectangular 45° wedged field for the 8 MV photon beam of a Varian 2100C. Data are plotted according to the side of the equivalent square obtained by Eq. (4.9) with $k = 1.5$.

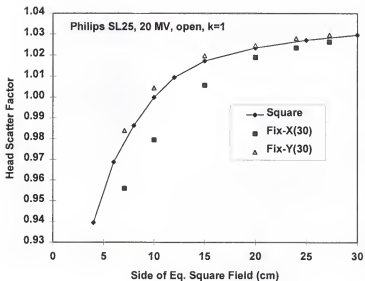


Figure 4-6. Head scatter factor as a function of a rectangular open field for the 20 MV photon beam of a Philips SL25.

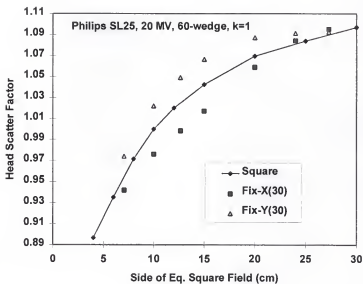


Figure 4-7. Wedge-head scatter factor as a function of a rectangular 60° wedged field for the 20 MV photon beam of a Philips SL25.

(Sterling et al. 1964). In Figures 4-8 and 4-9, the same data are plotted according to the side of the square field obtained by the modified equivalent square formalism. The geometric weighting factor $k = 1.85$ is obtained for the Philips SL25. The magnitude of the difference in output caused by the collimator exchange effect ranges from 0.3% to 3% for open and 0.4% to 5% for wedged fields. The modified equivalent square formalism provides output with a difference of less than about 1% for both open and wedged fields.

Discussion

The top edge of the collimator was considered to be the field-determining edge for calculation of the geometric weighting factor k . Although the distance from the source plane to the top of the collimator, l_{ix} or l_{iy} , changes according to the field size because of the circular movement, the amount of variation is negligible. Therefore, one value of l_{ix} or l_{iy} can be used. Interestingly, our formula has the same format as the formula that was empirically obtained by Vadash and Bjärngard (1993). In this study, $k = 1.5$ for the Varian 2100C and $k = 1.85$ for the Philips SL25 were obtained. Vadash and Bjärngard (1993) empirically obtained $k = 1.92$ for open fields and $k = 1.84$ for wedged fields for the Philips SL25 25MV photon beam, and Yu et al. (1995) obtained $k = 1.7$ for the Varian 2300CD 6 MV photon beam. Equation (4.9) shows that the equivalent field size varies slightly according to k . For example, the equivalent square field size for a 5×20 cm² (or 20×5 cm²) field is 9.1×9.1 cm² (or 7.1×7.1 cm²) with $k = 1.5$, and 9.5×9.5

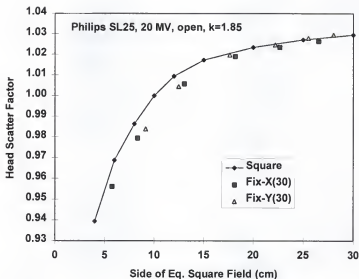


Figure 4-8. Head scatter factor as a function of a rectangular open field for the 20 MV photon beam of a Philips SL25. Data are plotted according to the side of the equivalent square obtained by Eq. (4.9) with $k = 1.85$.

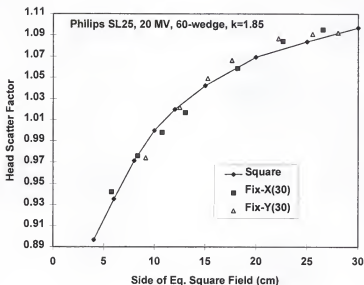


Figure 4-9. Wedge-head scatter factor as a function of a rectangular 60° wedged field for the 20 MV photon beam of a Philips SL25. Data are plotted according to the side of the equivalent square obtained by Eq. (4.9) with $k = 1.85$.

cm^2 (or $6.9 \times 6.9 \text{ cm}^2$) with $k = 1.7$. And the difference of head scatter factors between 9.1×9.1 and $9.5 \times 9.5 \text{ cm}^2$ (or 7.1×7.1 and $6.9 \times 6.9 \text{ cm}^2$) fields is about 0.2%.

The wedge-head scatter factor of a wedged field depends on both the scatter from scatterers in the head like the flattening filter and scatter from the wedge itself. The scattered radiation from a wedge depends on the area of the wedge that intercepts the radiation coming downstream through the treatment head. If the wedge is located above the collimator jaws like that in a Philips machine, the detector's eye view field at the source plane can be used for both head scatter and wedge scatter. However, when the wedge is located underneath the secondary collimator like that in a Varian machine equipped with an MLC, the field size for the wedge scatter contribution is different from the field size for the head scatter contribution. Whereas the head scatter contribution is determined by the field seen by the detector's eye view, the wedge scatter contribution depends on the field size projected at the detector plane. Therefore, in this case, the formula shown as Eq. (4.9) may slightly overcompensate for the collimator exchange effect. Our results for wedge-head scatter in Figure 4-5 show that Eq. (4.9) gives an accurate calculation of output even for a Varian-type wedged field.

Conclusion

The equivalent square field formula (Eq. [4.9]) with the geometric weighting factor (Eq. [4.10]) provides an accurate estimate of output even when there is a significant collimator exchange effect in a linear accelerator. Since only the geometric

weighting factor is considered, this formula is very simple and is applicable to any accelerator as long as the geometric data are known. Also, this formula can be used directly with conventional dosimetric data, which are always measured for a set of square fields at isocenter. It is not necessary to measure data for a series of rectangular fields (except for verification) for parametrization, as has been discussed extensively in the literature.

CHAPTER 5

A GENERALIZED SOLUTION FOR THE CALCULATION OF IN-AIR OUTPUT FACTORS IN IRREGULAR FIELDS

Introduction

Most treatment fields used in radiation therapy are irregular in shape while the dosimetry data is measured with square or rectangular fields. Conventionally, the in-phantom dosimetric parameters, such as the tissue-air-ratio (TAR) or tissue-maximum-ratio (TMR), are calculated based on the actual field shape created by a custom Cerrobend block, but the in-air output factor calculation is based on the rectangular field shaped by collimator jaw (secondary collimator), and is considered independent of any tertiary blocking (Kahn 1994). This conventional method for the calculation of in-air output of irregular field is valid when the size of irregular field is close to the size of collimator jaw opening. However, if the irregular field is much smaller than the collimator jaw opening or is extremely irregular so that part of block is close to central axis, the measured in-air output can be significantly different from the one obtained with conventional methods. Many authors have studied the physical origin of in-air output factors (Patterson & Shragge 1981, Kase & Svensson 1986, Mohan et al. 1985, Huang et al. 1987, Luxton & Astrahan 1988, Chaney & Cullip 1994, Zhu & Bjärngard 1995). It is primarily due to the amount of scattered radiation that is produced within the accelerator head structure and the fraction that can reach the point of measurement as the position of

the collimators is varied. There are several components in the head which produce scatter radiation. The flattening filter is considered to be the most dominant source of scattered radiation from the head (Kase & Svensson 1986, Mohan et al. 1985, Luxton & Astrahan 1988, Chaney & Cullip 1994). When a tertiary collimator, such as a conventional Cerrobend block or MLC installed below the field-defining secondary collimators, is used for field shaping, scatter radiation from the tertiary collimator may not be negligible, especially for small tertiary collimator openings with a large secondary collimator setting. The scatter radiation from beam modifiers such as physical wedges or compensators, can also be significant. There are several models which have appeared in the literature that accurately describe the scatter photon energy fluence distribution emanating from the head (Ahnesjö et al. 1992, Ahnesjö 1994, Dunscombe & Nieminen 1992, Yu & Sloboda 1993, Jaffray et al. 1993). However, these model-based approaches, which are based on uniform (Ahnesjö et al. 1992), triangular (Ahnesjö 1994), Gaussian (Dunscombe & Nieminen 1992), combination of several functions (Yu & Sloboda 1993), and experimentally determined distribution functions (Jaffray et al. 1993) require sophisticated programming and/or complex measurements. Moreover, most of these studies have mainly concentrated on the modeling of scatter radiation from the flattening filter. Recently, a method of parametrization with the equivalent square at the flattening filter was studied (Lam et al. 1996) and a similar approach, in which the parametrization was kept at the detector plane, was studied in the previous chapter (see Chapter 4). These studies have been limited to rectangular fields only.

In this chapter, an in-air output calculation formalism was set up and a simple algorithm for calculation of in-air output factor of irregular shaped fields was developed for both open and wedged fields by expanding the application of field mapping method that is based on detector's eye view field which has been successfully applied to rectangular fields (see Chapter 4).

In the algorithm, three major scatter contributors--flattening filter, wedge, and tertiary collimator--are considered. For the calculation of flattening filter scatter, first, the collimator jaw field and tertiary collimator shaped field are projected into the source plane through the detector's eye view to get a combinational field shape. Clarkson integration (Clarkson 1941) is carried out on the combined field using measured data at the detector plane in conjunction with field mapping method, instead of describing a discrete scatter source function that has been described in the literature. In the field mapping method, a field at the source plane is segmented and each segment field is mapped into a corresponding field at the detector plane by using equivalent field relationships obtained in Chapter 3. The algorithm is also valid for the treatment machines in which MLC replaces the upper or lower collimator jaw instead of being a tertiary collimator system. In that case only one projected field is used since there is no additional field. For a machine in which the MLC replaces the upper collimator jaws, Palta et al. (1996) have suggested an equivalent field method at the detector plane. Although equivalent field method at the detector plane provides a simple methodology, it does not explicitly account for both the collimator jaw exchange effects and non-linearity of in-air output dependence on field size.

The change of scatter radiation from tertiary collimator was also measured and parametrized. In the calculation of total head scatter factor, the tertiary collimator scatter factor is added to the collimator scatter factor.

In the case of wedged fields, the in-air output is dependent not only on scatter from flattening filter but also scatter from the wedge itself. Therefore, the relative position of the collimators (both secondary collimator and tertiary collimator) and wedge will determine the method of calculation of in-air output. When wedge is below the tertiary collimator (e.g., external wedge), the field size for wedge scatter contribution is different from the field size for head scatter contribution. The conventional collimator scatter factor for wedged field is separated into two components: one for the change of scatter radiation from flattening filter and the other for the change of scatter radiation from the wedge. Each component is independently calculated using a field mapping method with corresponding detector's eye view field sizes.

Formalism of In-air Output Factor

Head Scatter Factor and Monitor Back Scatter Factor

The total energy fluence in air on central axis produced by an external photon beam can be divided into two components: one is due to unscattered primary photons from the target and the other is due to scattered photons, which are generated in scattering materials in the head (for example, primary collimator, flattening filter, and field defining collimators).

$$\begin{aligned}\Psi &= \Psi_p + \Psi_s \\ &= \Psi_p \left(1 + \frac{\Psi_s}{\Psi_p} \right),\end{aligned}\quad (5.1)$$

where, Ψ_p is the energy fluence due to primary photons, Ψ_s is the energy fluence due to scatter photons from the scattering materials in the head. Considering the effect of backscatter radiation to the monitor chamber (Lam et al. 1996, Ahnesjö et al. 1992, Patterson & Shragge 1981, Luxton & Astrahan 1988, Moyer 1978, Higgins et al. 1989, Kubo & Lo 1989, Kubo 1989, Duzenli et al. 1993), primary energy fluence can be expressed as

$$\Psi_p(X_c, Y_c) = \Psi_p(\infty, \infty) f_{mb}(X_c, Y_c), \quad (5.2)$$

where, (X_c, Y_c) is secondary collimator setting, $\Psi_p(\infty, \infty)$ is unperturbed energy fluence, and f_{mb} is the function which accounts for the monitor backscatter effect on the energy fluence. By both multiplying and dividing Eq. (5.2) with monitor backscatter effect function, $f_{mb}(X_r, Y_r)$ for a reference collimator setting, (X_r, Y_r) , we can get

$$\begin{aligned}\Psi_p(X_c, Y_c) &= \Psi_p(\infty, \infty) f_{mb}(X_c, Y_c) \frac{f_{mb}(X_r, Y_r)}{f_{mb}(X_r, Y_r)} \\ &= \Psi_p(\infty, \infty) f_{mb}(X_r, Y_r) \frac{f_{mb}(X_c, Y_c)}{f_{mb}(X_r, Y_r)} \\ &= \Psi_p(X_r, Y_r) S_{mb}(X_c, Y_c),\end{aligned}\quad (5.3a)$$

where, (X_r, Y_r) is secondary collimator setting for the reference field and S_{mb} is monitor backscatter factor, defined as,

$$S_{mb}(X_c, Y_c) = \frac{f_{mb}(X_c, Y_c)}{f_{mb}(X_r, Y_r)}. \quad (5.3b)$$

Now, consider head scatter contribution. For the energy fluence of any field, we can get,

$$\begin{aligned}\Psi(X_c, Y_c) &= \Psi(X_c, Y_c) \frac{\Psi(X_r, Y_r)}{\Psi(X_r, Y_r)} \\ &= \Psi(X_r, Y_r) \frac{\Psi(X_c, Y_c)}{\Psi(X_r, Y_r)}.\end{aligned}\quad (5.4)$$

By substituting Eq. (5.1) into Eq. (5.4), we have

$$\Psi(X_c, Y_c) = \Psi(X_r, Y_r) \frac{\Psi_p(X_c, Y_c) \left(1 + \frac{\Psi_s(X_c, Y_c)}{\Psi_p(X_c, Y_c)}\right)}{\Psi_p(X_r, Y_r) \left(1 + \frac{\Psi_s(X_r, Y_r)}{\Psi_p(X_r, Y_r)}\right)}.\quad (5.5)$$

Using Eq. (5.3a), we can get,

$$\Psi(X_c, Y_c) = \Psi(X_r, Y_r) S_{mb}(X_c, Y_c) S_{hs}(X_c, Y_c)\quad (5.6a)$$

with head scatter factor, S_{hs} , defined as

$$S_{hs}(X_c, Y_c) = \frac{\left(1 + \frac{\Psi_s(X_c, Y_c)}{\Psi_p(X_c, Y_c)}\right)}{\left(1 + \frac{\Psi_s(X_r, Y_r)}{\Psi_p(X_r, Y_r)}\right)}.\quad (5.6b)$$

From the conventional definition of collimator scatter factor, S_c , we can get

$$\begin{aligned}S_c(X_c, Y_c) &= \frac{\Psi(X_c, Y_c)}{\Psi(X_r, Y_r)} \\ &= S_{mb}(X_c, Y_c) S_{hs}(X_c, Y_c).\end{aligned}\quad (5.7)$$

Equations (5.6) and (5.7) show that we can separate collimator scatter factor, S_c , into two components, monitor back scatter factor, S_{mb} , and head scatter factor, S_{hs} . When a field is

very small, source obscuring may occur. In that case, a source obscuring factor should be included in the Eq. (5.7) (Zhu & Bjärngård 1995).

Presence of A Beam Modifier in The Field

When photon beam passes a beam modifier (for example, a wedge), the energy fluence changes due to both attenuation of incident photons and scatter photons produced in the beam modifier. If we denote the energy fluence below the beam modifier as Φ , then, we can express

$$\begin{aligned}\Phi &= \Phi_u + \Phi_s \\ &= \Phi_u \left(1 + \frac{\Phi_s}{\Phi_u} \right),\end{aligned}\quad (5.8)$$

where Φ_u is the unscattered energy fluence which is due to the primary head scattered photons and Φ_s is the energy fluence due to scatter photons by the beam modifier. With attenuation factor of beam modifier, A_{bm} , Φ_u is given by

$$\Phi_u = A_{bm} \Psi, \quad (5.9)$$

where Ψ is the total energy fluence incident on the beam modifier, expressed in Eq. (5.1). For the energy fluence of any field with beam modifier, we can get,

$$\begin{aligned}\Phi(X_c, Y_c) &= \Phi(X_c, Y_c) \frac{\Phi(X_r, Y_r)}{\Phi(X_r, Y_r)} \\ &= \Phi(X_r, Y_r) \frac{\Phi(X_c, Y_c)}{\Phi(X_r, Y_r)}.\end{aligned}\quad (5.10)$$

By substituting Eq. (5.8) into Eq. (5.10),

$$\Phi(X_c, Y_c) = \Phi(X_r, Y_r) \frac{\Phi_w(X_c, Y_c) \left(1 + \frac{\Phi_s(X_c, Y_c)}{\Phi_w(X_c, Y_c)}\right)}{\Phi_w(X_r, Y_r) \left(1 + \frac{\Phi_s(X_r, Y_r)}{\Phi_w(X_r, Y_r)}\right)} \quad (5.11)$$

is obtained. Using Eq. (5.9) and (5.7), we can get,

$$\Phi(X_c, Y_c) = \Phi(X_r, Y_r) S_{mb}(X_c, Y_c) S_{bw}(X_c, Y_c) S_{bms}(X_c, Y_c), \quad (5.12a)$$

with beam modifier scatter factor, S_{bms} , defined as

$$S_{bms}(X_c, Y_c) = \frac{\left(1 + \frac{\Phi_s(X_c, Y_c)}{\Phi_w(X_c, Y_c)}\right)}{\left(1 + \frac{\Phi_s(X_r, Y_r)}{\Phi_w(X_r, Y_r)}\right)}. \quad (5.12b)$$

In the derivation of Eq. (5.12), we assumed the dependency of A_{bm} on field size is negligible. When wedge is used as a beam modifier, using the standard convention of collimator scatter factor of wedged field, $S_{c,w}$, we can get

$$\begin{aligned} S_{c,w}(X_c, Y_c) &= \frac{\Phi(X_c, Y_c)}{\Phi(X_r, Y_r)} \\ &= S_{mb}(X_c, Y_c) S_{bw}(X_c, Y_c) S_{ws}(X_c, Y_c) \\ &= S_c(X_c, Y_c) S_{ws}(X_c, Y_c), \end{aligned} \quad (5.13)$$

where S_{bms} is replaced with wedge scatter factor, S_{ws} in order to indicate wedge is the beam modifier. Equations (5.12) and (5.13) show we can separate wedge scatter factor, S_{ws} , from conventional collimator scatter factor of wedge field, $S_{c,w}$.

A Shaped Field with A Tertiary Collimator

Tertiary collimator, such as conventional Cerrobend block and Varian type MLC, can change the in-air output factors. There are two components. One is the change of head scatter factor, S_{hs} due to the change of detector's eye view of head scatter area. The other is scatter photons produced in the tertiary collimator itself which, in some cases, may not be negligible. If we let the energy fluence below the tertiary collimator as φ , then, we can express

$$\varphi = \varphi_u + \varphi_s, \quad (5.14)$$

where φ_u is the energy fluence coming from upstream of the tertiary collimator and φ_s

is the energy fluence due to scatter photons by the tertiary collimator. We define

$\varphi_s(X_c, Y_c)$ as energy fluence due to scattered photons that emanate from a solid material of same thickness and composition as tertiary collimator with $X_c \times Y_c$ collimator setting.

For a field with tertiary collimator, we get,

$$\varphi(X_c, Y_c, X_{tc}, Y_{tc}) = \varphi_u(X_c, Y_c, X_{tc}, Y_{tc}) + \varphi_s(X_c, Y_c) = \frac{\Psi(X_c, Y_c)}{\Psi(X_{tc}, Y_{tc})} \varphi_s(X_{tc}, Y_{tc}), \quad (5.15)$$

where (X_{tc}, Y_{tc}) is setting of the tertiary collimator. Without tertiary collimator,

$(X_{tc}, Y_{tc}) = (\infty, \infty)$ and φ_u is the same as Ψ , that is,

$$\varphi_u(X_c, Y_c, \infty, \infty) = \Psi(X_c, Y_c). \quad (5.16)$$

By both multiplying and dividing with $\Psi(X_r, Y_r)$ to Eq. (5.15), we can get

$$\varphi(X_c, Y_c, X_{lc}, Y_{lc}) = \Psi(X_r, Y_r)$$

$$\times \left[\frac{\varphi_u(X_c, Y_c, X_{lc}, Y_{lc})}{\Psi(X_r, Y_r)} + \frac{\varphi_s(X_c, Y_c)}{\Psi(X_r, Y_r)} - \frac{\Psi(X_c, Y_c)}{\Psi(X_{lc}, Y_{lc})} \frac{\varphi_s(X_{lc}, Y_{lc})}{\Psi(X_r, Y_r)} \right] \quad (5.17)$$

Then, collimator scatter factor for a shaped field with tertiary collimator, $S_{t,c}$, is given by

$$\begin{aligned} S_{t,c}(X_c, Y_c, X_{lc}, Y_{lc}) &= \frac{\varphi(X_c, Y_c, X_{lc}, Y_{lc})}{\Psi(X_r, Y_r)} \\ &= \left[\frac{\varphi_u(X_c, Y_c, X_{lc}, Y_{lc})}{\Psi(X_r, Y_r)} + \frac{\varphi_s(X_c, Y_c)}{\Psi(X_r, Y_r)} - \frac{\Psi(X_c, Y_c)}{\Psi(X_{lc}, Y_{lc})} \frac{\varphi_s(X_{lc}, Y_{lc})}{\Psi(X_r, Y_r)} \right] \\ &= S_c(X_c, Y_c, X_{lc}, Y_{lc}) + S_{lc}(X_c, Y_c) - \frac{\Psi(X_c, Y_c)}{\Psi(X_{lc}, Y_{lc})} S_{lc}(X_{lc}, Y_{lc}), \end{aligned} \quad (5.18a)$$

with tertiary collimator scatter factor, S_{lc} , defined as

$$S_{lc}(X, Y) = \frac{\varphi_s(X, Y)}{\Psi(X_r, Y_r)}. \quad (5.18b)$$

Calculation Algorithm

Open Field

Head scatter factor and field definition by DEV. The head scatter factor given in Eq. (5.6b) depends on head scattered radiation which can reach the detector. If any ray line of head scatter to the detector is blocked by tertiary collimator such as Cerrobend block or MLC, the head scatter factor will decrease. Therefore, S_{hd} is dependent on the field size

determined by detector's eye view instead of the collimator field size. The field defined by detector's eye view is illustrated in Figure 5-1. In Figure 5-1, l_{1x} , l_{1y} and l_{1T} are the distances from the source plane to the top of X , Y collimator jaws and tertiary collimator, respectively. The distances from the detector plane to the top of X , Y collimators, and tertiary collimator are noted as l_{2x} , l_{2y} , and l_{2T} . Now, let X_D , Y_D and T_D be the field sizes determined by the lower (or X), upper (or Y) collimator jaws and the tertiary collimator, respectively, at the detector plane and X_S , Y_S and T_S be the field sizes determined by the X , Y collimator jaw, and tertiary collimator at the source plane through the detector's eye view. Then, the field conversion factors from detector-to-source plane, k_x , k_y and k_T are given by

$$k_x = l_{1x}/l_{2x}, \quad (5.19)$$

$$k_y = l_{1y}/l_{2y}, \quad (5.20)$$

$$k_T = l_{1T}/l_{2T}. \quad (5.21)$$

Then, field sizes at the source plane, X_S , Y_S and T_S become

$$X_S = k_x X_D, \quad (5.22)$$

$$Y_S = k_y Y_D, \quad (5.23)$$

$$T_S = k_T T_D. \quad (5.24)$$

After the field size conversion from the detector plane to source plane, the projected collimator jaw and tertiary collimator shaped fields are combined in the source plane.

That is, the area common to both fields is used to determine head scatter factor.

Clarkson integration and field mapping. The head scatter factor is calculated by carrying out Clarkson integration in the combined field in the source plane. Typically,

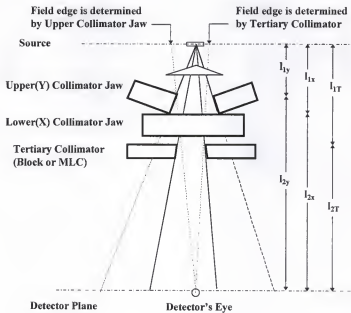


Figure 5-1. Schematic diagram showing the geometrical relationship among detector, X and Y collimator jaw settings, tertiary collimator settings, detector plane field size and source plane field size.

conventional dosimetric data is available only for square fields at detector plane.

Therefore, it is convenient to project source plane field to detector plane. For any circular field of radius, r_s at source plane, we can get equivalent square field at source plane, s_s^{eq} from equivalent field relationship for head scatter,

$$s_s^{eq}(r_s) = 1.8r_s. \quad (5.25)$$

It is necessary to find an equivalent square in the detector plane, s_D^{eq} which is equivalent to s_s^{eq} . If we project s_D^{eq} to source plane, the square field changes to the rectangular field, $k_x s_D^{eq} \times k_y s_D^{eq}$. Once again, by using the equivalent field relationship, we can let

$$s_s^{eq'} = [2k_x k_y / (k_x + k_y)] s_D^{eq}. \quad (5.26)$$

Since $s_s^{eq'}$ should match with s_s^{eq} , we can get an equivalent square field at detector plane, $s_D^{eq}(r_s)$ for the circular field, r_s at the source plane,

$$\begin{aligned} s_D^{eq}(r_s) &= [(k_x + k_y) / 2k_x k_y] s_s^{eq}(r_s) \\ &= 0.9[(k_x + k_y) / k_x k_y] r_s. \end{aligned} \quad (5.27)$$

The head scatter factor for irregular shaped open field is obtained by

$$S_{hs}(irregular) = (1/360) \sum_i S_{hs}(s_D^{eq}(r_s)) \Delta\phi_i, \quad (5.28)$$

where, $S_{hs}(s_D^{eq}(r_s))$ is the head scatter factor of the equivalent square field at detector plane which corresponds to circular field with radius r_s at source plane. And $\Delta\phi_i$ is i -th interval of angle in Clarkson summation. To get conventional collimator scatter factor, S_c , we must multiply Eq. (5.28) with monitor backscatter factor. Since monitor backscatter factor is primarily dependent on secondary collimator settings, we can multiply monitor backscatter factor of $X_D \times Y_D$ rectangular field at detector plane, that is, $S_{ms}(X_D, Y_D)$. We can rewrite Eq. (5.28) as,

$$\begin{aligned}
S_{bs}(irregular) &= S_c(irregular)/S_{mb}(X_D Y_D) \\
&= (1/360) \sum_i [S_c(s_D^{eq}(r_{Si})) / S_{mb}(s_D^{eq}(r_{Si}))] \Delta\phi_i,
\end{aligned} \tag{5.29a}$$

or,

$$S_c(irregular) = S_{mb}(X_D Y_D) (1/360) \sum_i [S_c(s_D^{eq}(r_{Si})) / S_{mb}(s_D^{eq}(r_{Si}))] \Delta\phi_i, \tag{5.29b}$$

where $S_c(s_D^{eq}(r_{Si}))$ is the collimator scatter factor of the equivalent square field at detector plane which corresponds to circular field with radius r_{Si} at source plane. Monitor backscatter factor can be measured by telescopic method (Kubo 1989). Ahnesjö et. al. (1992) assumed that the amount of backscatter to the monitor chamber from the back surface of a collimator jaw is proportional to the irradiated surface area. With same assumption, Lam et. al. (1996) modeled monitor back scatter factor as a function of collimator settings. When each segmented field is not much different from collimator settings, we can make an approximation,

$$S_c(irregular) = (1/360) \sum_i S_c(s_D^{eq}(r_{Si})) \Delta\phi_i, \tag{5.30a}$$

by assuming,

$$S_{mb}(X_D Y_D) \approx S_{mb}(s_D^{eq}(r_{Si})) \approx S_{mb}(s_D^{eq}(r_{Sj})) \approx \dots \tag{5.30b}$$

In most clinical situations, this expression is a good approximation. Equation (5.29) can be directly used with the measurement of monitor backscatter factor if a more accurate monitor backscatter factor is required. This will probably be necessary in the case of beam intensity modulation, in where very small shaped fields with large secondary collimator setting may be used.

Scatter Factor of Tertiary Collimator. Since the tertiary collimator transmits more radiation and is closer to the detector than collimator jaws, it is necessary to consider scatter contribution from tertiary collimator itself. The amount of scatter contribution is dependent on irradiated area of tertiary collimator. We define tertiary collimator scatter factor, $S_{tc}(s)$, as the ratio of scatter dose from a solid block material with $s \times s$ collimator setting to the dose of reference 10×10 field in Eq. (5.18b). Tertiary collimator scatter factor of an irregular shaped field with $X_D \times Y_D$ collimator jaw setting can be obtained as

$$S_{tc}(irregular) = S_{tc}(X_D, Y_D) - (1/360) \sum_i [S_c(X_D, Y_D)/S_c(s_D^{eq}(r_{Di}))] S_{tc}(s_D^{eq}(r_{Di})) \Delta\phi_i, \quad (5.31)$$

where $s_D^{eq}(r_{Di})$ is the equivalent square field at detector plane which gives same tertiary collimator scatter contribution as a circular field with radius r_{Di} at detector plane, and is obtained by $s_D^{eq}(r_{Di}) = 1.8r_{Di}$. When each segmented field is not much different from collimator settings, we can make an approximation,

$$S_{tc}(irregular) = S_{tc}(X_D, Y_D) - (1/360) \sum_i S_{tc}(s_D^{eq}(r_{Di})) \Delta\phi_i, \quad (5.32a)$$

by assuming,

$$S_c(X_D, Y_D) \approx S_c(s_D^{eq}(r_{s1})) \approx S_c(s_D^{eq}(r_{s2})) \approx \dots \quad (5.32b)$$

Finally, in-air output factor for irregular open field, OF , becomes

$$OF(irregular) = S_c(irregular) + S_{tc}(irregular), \quad (5.33)$$

where S_c is obtained by Eq. (5.29b) or Eq. (5.30a) and S_{tc} is obtained by Eq. (5.31) or Eq. (5.32a). Note that the MLC on Varian linear accelerators, which is mounted below the X

and Y jaws, is handled the same way as a block except S_{es} that corresponds to the scatter from the leaves of the MLC system.

Wedged Field

Depending on the position of wedge, the method of in-air output factor calculation are different. On a Varian accelerator with MLC, a wedge is inserted underneath the tertiary collimator (MLC). In this case, the field size for wedge scatter contribution is different from the field size for head scatter contribution. It can be clearly seen from Figure 5-2 that the head scatter contribution is determined by the detector's eye view of the field defined by collimator jaws and the wedge scatter contribution is dependent on irregular field shaped by the tertiary collimator in the detector plane. To account for this fact, the collimator scatter factor for wedged field is separated into collimator scatter factor and wedge scatter factor as given in Eq. (5.13),

$$S_{c,w} = S_c S_{ws} . \quad (5.34)$$

Therefore,

$$S_{ws} = S_{c,w} / S_c . \quad (5.35)$$

For an irregular field, each component is calculated by,

$$S_c(irregular) = (1/360) \sum_i S_c(s_D^{eq}(r_{Si})) \Delta\phi_i , \quad (5.36a)$$

with

$$s_D^{eq}(r_{Si}) = 0.9[(k_x + k_y)/k_x k_y] r_{Si} ,$$

and

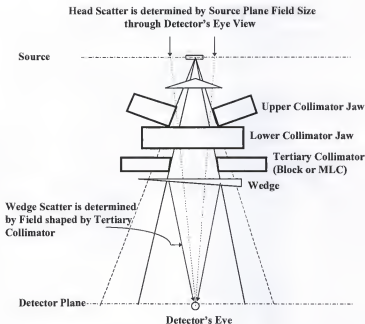


Figure 5-2. Schematic diagram showing the detector's eye view scatter area for head scatter and wedge scatter in Varian type (external) wedged MLC field.

$$S_{ws}(\text{irregular}) = (1/360) \sum_i S_{ws}(s_D^{eq}(r_{Di})) \Delta\phi_i, \quad (5.36b)$$

with

$$s_D^{eq}(r_{Di}) = 1.8 r_{Di}.$$

Finally, in-air output factor for irregular wedged field is obtained by

$$OF_w(\text{irregular}) = S_c(\text{irregular}) S_w(\text{irregular}). \quad (5.37)$$

Note that the scatter contribution from the tertiary collimator is not considered since wedge is underneath the tertiary collimator.

If the wedge is located above the collimator jaws, the field size for wedge scatter contribution is the same as that for head scatter contribution. That is, the collimator scatter factor of a wedge field, $S_{c,w}$, is given by

$$S_{c,w}(\text{irregular}) = [(1/360) \sum_i S_c(s_D^{eq}(r_{Si})) \Delta\phi_i] [(1/360) \sum_i S_{wt}(s_D^{eq}(r_{Si})) \Delta\phi_i], \quad (5.38)$$

and the in-air output factor of a wedge field, OF_w , is obtained by

$$OF_w(\text{irregular}) = S_{c,w}(\text{irregular}) + S_{b,w}(\text{irregular}),$$

where $S_{b,w}$ is the block scatter factor for a wedged beam. In Eq. (38), $s_D^{eq}(r_{Si})_c$ is the equivalent square field at the detector plane for head scatter contribution and is the same as for Eq. (27). However, the equivalent square field at the detector plane for wedge scatter contribution, $s_D^{eq}(r_{Si})_{ws}$, is not the same as $s_D^{eq}(r_{Si})_c$. From the equivalent field relationship,

$$s_S^{eq}(r_S) = 1.8 r_S. \quad (5.39)$$

If we project s_D^{eq} (an equivalent square at detector plane) to the source plane, the square field changes to a rectangular field, $k_x s_D^{eq} \times k_y s_D^{eq}$. Using the equivalent field relationship for wedge scatter, we can let

$$s_S^{eq} = (k_x k_y)^{1/2} s_D^{eq}. \quad (5.40)$$

Because Eq. (5.39) and Eq. (5.40) should match each other, we can get the equivalent square field at the detector plane, $s_D^{eq}(r_s)$, for any circular field with a radius of r_s at the source plane:

$$s_D^{eq}(r_s)_{ws} = 1.8 r_s / (k_x k_y)^{1/2}. \quad (5.41)$$

Methods and Materials

In-air output factors of tertiary collimator shaped fields were measured with a cylindrical acrylic mini-phantom as described by van Gasteren et al. (1991). The cylindrical phantom is 3.8 cm in diameter and 15 cm long. A shonka plastic 0.1 cc ionization chamber was inserted in the mini-phantom with its center located at 5 cm from the front surface and 100 cm from the source. Measurements were taken on a Varian 2100C with 8 MV photon for both open and wedge fields. Since wedge can not be used with conventional block in Varian machine that is equipped with MLC, only MLC fields were considered with wedges. The measurements were taken with the fixed X and Y collimator jaw settings ($22.5 \times 22.5 \text{ cm}^2$ for Cerrobend block field, $21.6 \times 20.4 \text{ cm}^2$ for open MLC field, and $20 \times 20 \text{ cm}^2$ for wedged MLC field). The tertiary collimated field sizes were varied for 4×4 to $20 \times 20 \text{ cm}^2$ for both open and 45° wedge field (for

systematic analysis of calculated data, only square shapes were devised with tertiary collimator instead of irregular shape fields). Special care was taken to position the chamber on the central axis for measurements with wedge. Reversing the wedge direction did not change the measured readings by more than 0.4%. In the case of open field, scatter contribution from tertiary collimator (Cerrobend block and Varian MLC) was also measured with the same mini-phantom as described above. A set of measurements were made underneath a solid piece made out of the same material as the tertiary collimator material (Cerrobend or MLC) with field sizes ranging from 4×4 to $20 \times 20 \text{ cm}^2$. The thickness of Cerrobend block was 7.5 cm. The data were extrapolated to $0 \times 0 \text{ cm}^2$ field. The fluence of $(0,0)$ field multiplied by $S_c(X,Y)/S_c(0,0)$ was subtracted from total fluence for each field size, (X,Y) . The remaining fluence of each field is divided by the fluence of $10 \times 10 \text{ cm}^2$ reference open field to get tertiary collimator (block or MLC) scatter factor, S_{sc} . Finally, in-air output factors of two irregular fields were also measured. One shape was made with Cerrobend material and the other was made with MLC. Figures 5-3 and 5-4 show beam's eye view of block and MLC shaped irregular fields projected at the detector plane, respectively. For all these experimental measurements, in-air output factors were calculated using the algorithm described in the previous section.

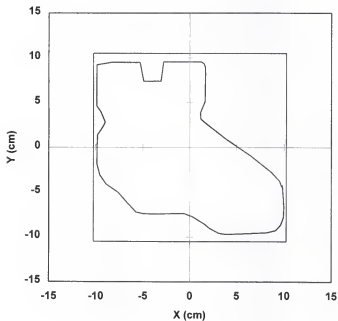


Figure 5-3. A beam's eye view irregular field shaped by Cerrobend block at detector plane. Outer rectangle indicates collimator jaw setting at detector plane. Both 8 and 18 MV photon beams of Varian 2100C were used.

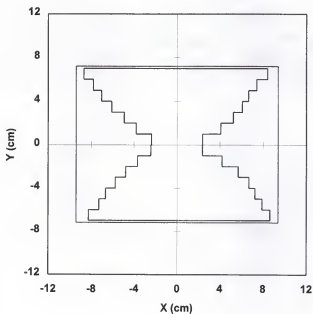


Figure 5-4. A beam's eye view irregular field shaped by MLC at detector plane. Outer rectangle indicates collimator jaw setting at detector plane. Both 8 and 18 MV photon beams of Varian 2100C were used.

Results

Tertiary Collimator Scatter Factor

The measured tertiary collimator scatter factor, S_{sc} for Cerrobend block and Varian MLC are shown in Figure 5-5. As defined in Eq. (5.18b), $S_{sc}(20,20)$ for blocked field is the ratio of energy fluence due to scattered photons from a $20 \times 20 \text{ cm}^2$ solid Cerrobend block to energy fluence of a $10 \times 10 \text{ cm}^2$ open field at the reference point. Therefore, for a $20 \times 20 \text{ cm}^2$ completely blocked field, energy fluence due to scattered photons is 1.3 % of energy fluence of $10 \times 10 \text{ cm}^2$ open field. As an example, The value of S_{sc} for a Cerrobend block with outer dimension of $20 \times 20 \text{ cm}^2$ and inner dimension of $15 \times 15 \text{ cm}^2$ from Figure 5-5 is 0.005. This is the difference in $S_{sc}(20,20)$ and $S_{sc}(15,15)$ values. The tertiary collimator scatter factors for Cerrobend block are almost twice as large as those for MLC. Two possible reasons for this may be that the block is closer to the detector than MLC and that it has larger transmission than MLC.

In-air Output Factor of Open Fields Defined by Tertiary Collimator

In-air output factors for open fields were calculated using Eqs. (5.30a), (5.32a), and (5.33). The calculated data for fields shaped with Cerrobend block and MLC are compared with measured data in Figures 5-6 and 5-7, respectively. Note that the secondary collimator settings were fixed for these measurements. The settings were $22.5 \times 22.5 \text{ cm}^2$ for Cerrobend block and $21.6 \times 20.4 \text{ cm}^2$ for MLC shaped fields. Two other alternate methods of obtaining in-air output factors are also shown for comparison. One

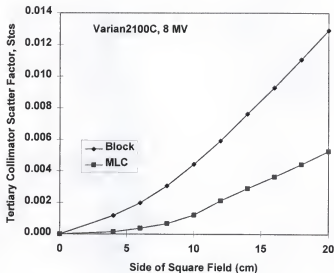


Figure 5-5. Tertiary collimator scatter factor for 8 MV photon beam of Varian 2100C. Where tertiary collimator scatter factor is defined as the ratio of scatter dose from solid tertiary collimator material (Cerrobend block or Varian type MLC) to the dose of reference $10 \times 10 \text{ cm}^2$ open field at detector plane.

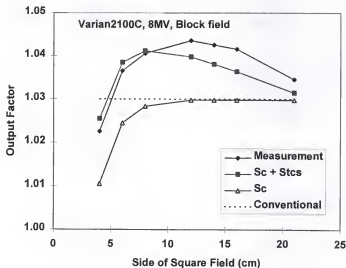


Figure 5-6. In-air output factor of open fields with Cerrobend block tertiary collimator for 8 MV photon beam of Varian 2100C. While the collimator jaw setting is fixed as $22.5 \times 22.5 \text{ cm}^2$, block shaped field is changed from 4×4 to $21 \times 21 \text{ cm}^2$ at detector plane.

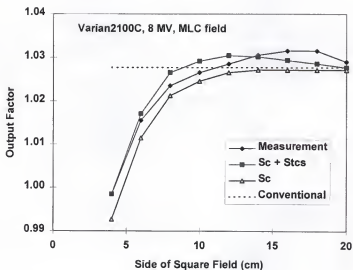


Figure 5-7. In-air output factor of open field with MLC tertiary collimator for 8 MV photon beam of Varian 2100C. While the collimator jaw setting is fixed as $21.6 \times 20.4 \text{ cm}^2$, MLC shaped field is changed from 4×4 to $20 \times 20 \text{ cm}^2$ at detector plane.

of the methods is labeled as conventional method in which it is assumed that the in-air output depends on only X and Y secondary collimator jaw settings and is independent of tertiary collimator. The other method is labeled as S_c method. This is simply a field mapping method through detector's eye view field and it does not include tertiary collimator scatter factor. It is obvious from Figures 5-6 and 5-7 that the conventional method of calculating in-air in-air output factor is grossly inadequate when the tertiary collimated field is much smaller than the secondary collimator opening. This is attributed to the screening of head scattered photon fluence by the tertiary collimator. Field mapping method through DEV field predicts the behavior of in-air output very well but it underestimates the in-air output if the tertiary collimator scatter factor is not included. Once the tertiary collimator scatter factor is included, the agreement between the calculated in-air output and measured in-air output for all field sizes is very good (within 0.5 %). However, for fields defined with MLC, the agreement between the calculated in-air output and measured in-air output is fairly good with field mapping method through DEV field even if tertiary collimator scatter factor is not included. This is primarily due to the small scatter contribution from MLC.

In-air Output Factor of Varian Type Wedge (External Wedge) Fields

Wedge scatter factor, S_{wp} , for 45° wedge was obtained by Eq. (5.35) and is shown in Figure 5-8. In the Figure 5-8 for field sizes 4×4 to $20 \times 20 \text{ cm}^2$. The data were extrapolated to 0×0 field. Using the Eq. (5.36) and (5.37), in-air output factor of wedge field was calculated and compared with measured data in Figure 5-9. Since block can not

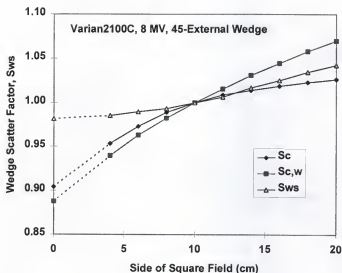


Figure 5-8. Wedge scatter factor, S_{ws} of 45° wedge field for 8 MV photon beam of Varian 2100C. Wedge scatter factor is obtained by dividing the collimator scatter factor of wedge field, $S_{c,w}$, with collimator scatter factor of open field, S_c .

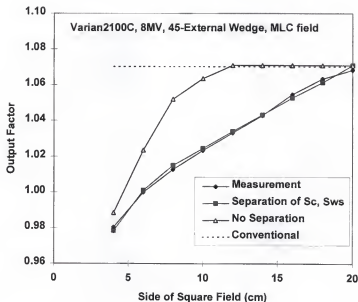


Figure 5-9. In-air output factor of wedge field with MLC tertiary collimator for 8 MV photon beam of Varian 2100C. While the collimator jaw setting is fixed as $20 \times 20 \text{ cm}^2$, MLC shaped field is changed from 4×4 to $20 \times 20 \text{ cm}^2$ at detector plane.

be used with wedge in Varian 2100C, only MLC fields were considered. In-air output factors obtained by conventional method and field mapping method with DEV field without separating S_{ws} were also plotted for comparison. Conventional method gives one in-air output factor value for all field sizes. Field mapping method through DEV field without separating S_{ws} always overestimated the in-air output with the differences reaching to about 4 %. The separation of S_c and S_{ws} shows good agreement (within 0.5 % difference) with experimental data for all field sizes.

In-air Output Factor of Irregular Shaped Fields

In-air output factors for irregular fields were calculated and compared with experimental data in Table 5-1 for both 8 and 18 MV photon beams. The experimental data were also measured with 18 MV photon beam available on the same Varian 2100C and compared with the calculated data to verify the validity of algorithm for other photon energies. Calculated in-air output factors matched well with the measurements. The maximum difference was less than 0.5 %. In-air output factors obtained by conventional method were also tabulated in Table 5-1 for comparison. The conventional method tends to overestimate in-air output in the presence of wedges and underestimate for open fields.

Discussion

The importance of piecewise separation of scatter radiation component in the in-air output from a linear accelerator obvious from the measured data are shown in Figures

Table 5-1. In-air output factors of test irregular fields for 8 and 18 MV photon beams of Varian 2100C. Data are normalized to reference $10 \times 10 \text{ cm}^2$ field. In-air output factors obtained by conventional method are also included for comparison. Beam's eye view irregular field shapes are shown in Figures 5-3 and 5-4.

Tertiary Collimator	Energy (MV)	In-air Output		
		Measurement	Calculation	Conventional
Block(open)	8	1.034	1.031	1.026
	18	1.032	1.028	1.024
MLC(open)	8	1.013	1.012	1.020
	18	1.012	1.010	1.017
MLC(45° wedge)	8	1.021	1.021	1.047
	18	1.020	1.018	1.041

5-6, 5-7, and 5-9. A close examination of Figure 5-6 shows that as the field is increasingly blocked, the relative in-air output starts to increase first and then decreases as the field blocking becomes extreme. This is attributed to increasing scatter from the tertiary collimator and decreasing head scatter as the field is progressively blocked. A simple geometrical back projection of the field to the source plane that accounts for the head scatter is not sufficient to predict the in-air output accurately. The tertiary collimator scatter from field shaping blocks must be included to achieve better accuracy. Even the calculations show lower relative in-air output than measured data for larger tertiary collimated fields. The reason for this small difference can be attributed to the scatter

contribution from side wall of tertiary collimator that is not included in our calculation model. Figure 5-7 indicates that the amount of scatter contribution from MLC is not significant. Therefore, it may not be necessary to consider MLC scatter factor for in-air output calculation as long as head scatter is calculated accurately. But the inclusion of scatter from MLC gives better accuracy. The importance of separating scatter component from the head and beam modifier (wedge) is clearly demonstrated in Figure 5-9. Thicker wedges introduce significant amount of scatter. The magnitude of scattered radiation from an external wedge is dependent upon the surface area of the wedge seen by the photon fluence that is incident on it.

Scatter source distribution functions described in the literature have been defined within the physical dimension of flattening filter. In reality, in-air output may change even when the field size becomes larger than the flattening filter dimension. If this effect is not considered, the calculation can result in an increasing discrepancy with measurement. To account for this effect, Yu and Sloboda (1993) assumed a pseudo source distribution function outside the flattening filter and it is determined by experiment for each beam. In field mapping method, since measurement data is directly used combined with equivalent field relationships, this effect is inherently included, thus, no additional experiment is required.

When the source-to-detector (SDD) distance changes, the inverse law has been used to calculate in-air output change. As the detector point changes, the field through detector's eye view also changes. Therefore, the effective field size for inverse square law calculation should be changed and this can be easily done with field conversion factors

specific for each detector point. This effect may not be negligible with very small field size because the gradient of in-air output change is much steeper in smaller field sizes than larger field sizes. However, it is not easy to separate these two effects, pure inverse square law and DEV field size change due to SDD change. It is found the effective source position of photon beam is not the same as physical source position in megavoltage linear accelerators (Tatcher & Bjärngard 1992, McKenzie & Stevens 1993). The effective source position can be easily determined by experiments (Tatcher & Bjärngard 1992). When a effective source position is determined by experiments with fixed field size for all SDD (Tatcher & Bjärngard 1992), it inherently includes the effect of field size change.

However, there are two complications for external wedge field: 1) effective source position is dependent on field size, and 2) field sizes for head scatter and wedge scatter are different each other when tertiary collimator is used. Therefore, it may be necessary to separate each effective source position corresponding to each scatter source.

Conclusion

An in-air output factor calculation algorithm based on field mapping through the detector's eye view field was developed and programmed. This method can predict in-air output factor behavior in irregular fields with very good agreement for both open and wedge fields. Although source plane field size is used to determine the head scatter factor, parametrization at detector plane is kept by mapping the source plane field size

into the detector plane field size. That is, no additional dosimetric data acquisition is required, which makes it is very simple to implement this method. In order to include the scatter contribution from tertiary collimator, tertiary collimator scatter factor can be measured and parametrized. This gives more accurate prediction of in-air output, especially in the case of the use of Cerrobend block. By virtue of the simplicity, field mapping method through the detector's eye view field can be easily implemented in any clinic.

CHAPTER 6
TWO-EFFECTIVE-SOURCE METHOD FOR THE CALCULATION OF IN-AIR
OUTPUT FACTOR AT VARIOUS SDDs IN WEDGED FIELDS

Introduction

In megavoltage photon therapy, it has generally been assumed that in-air output at central axis varies proportional to the inverse square of SDD (Kahn 1994). That is, the in-air output factor is given by

$$OF(c, SDD) = OF(c_r, SDD_r)H(c)[SDD_r/SDD]^2, \quad (6.1)$$

where, c , r , and H indicate collimator opening, reference condition, and field size dependence of in-air output factor (collimator scatter factor, Sc), respectively.

Conventionally, the isocenter is chosen as the reference point of measurement. In most linear accelerators, SDD for isocenter is 100 cm.

In a megavoltage linear accelerator, the physical source of x-rays lies at the site where the electron beam hits the target. As the photons move forward, they pass through other structures in which they may undergo scattering interactions. Depending on the structure and collimator system, different amounts of scattered photons can reach the point of measurement. Therefore, one can expect that the contribution of these scattered photons will produce a downstream shift in the location of the effective x-ray source (Tatcher & Bjärngård 1992). This problem may be solved by using a one-effective-source

method combined with the inverse square law (Tatcher & Bjärngård 1992, McKenzie & Stevens 1993). That is, Eq. (6.1) can be replaced with

$$OF(c, SDD) = OF(c_n, SDD_e)H(c_{eff})[\{SDD_r - v_o(FS)\} / \{SDD - v_d(FS)\}]^2, \quad (6.2)$$

where, v_o is the distance to the effective source from the physical source. Effective field size, c_{eff} , accounts for the change of field size through detector's eye view, which can be obtained through field mapping with geometric field conversion factors specific for the linear accelerator (see Chapters 4 & 5). However, when an effective source position is obtained by experiments with a fixed field size (Tatcher & Bjärngård 1992, McKenzie & Stevens 1993), it inherently includes the effect of field size change. Furthermore, the effect of field size change is much smaller than the effect of inverse square law. Therefore, we can express Eq. (6.2) as

$$OF(c, SDD) = OF(c_n, SDD_e)H(c)[\{SDD_r - v(c)\} / \{SDD - v(c)\}]^2. \quad (6.3)$$

It has been shown in the literature that v is independent on field size for open field ($<v> = 1$ cm) (Tatcher & Bjärngård 1992, McKenzie & Stevens 1993). When one-effective-source method is applied for a wedge field, $SDD - v$ indicates the pseudo-source position of the sum of primary (head scatter) and wedge scatter radiation. However, v depends on field size and ranges from 2 - 4 cm (Tatcher & Bjärngård 1992). The literature is sparse on the effective source position in the presence of an external wedge. One would expect that the increased scatter from external wedges would move the effective source position further downstream from the target and that the position would be highly field-size dependent. Moreover, when a tertiary collimator is used with an external wedge, the field size for determination of wedge scatter is different from that for head scatter (see Chapter

5). This case may not be properly dealt with in Eq. (6.3) because v is obtained with one field size.

In this chapter, a simple algorithm for calculating in-air output factor at any SDD point on the central axis for wedged fields was developed. The method separately deals with wedge scatter source from head scatter source.

Theory

When photon beams pass a wedge, energy fluence changes because of both attenuation of incident photons and scatter photons by the wedge. If we express the energy fluence below the wedge as Φ , then, we can express

$$\begin{aligned}\Phi &= \Phi_u + \Phi_s \\ &= \Phi_u \left(1 + \frac{\Phi_s}{\Phi_u} \right),\end{aligned}\quad (6.4)$$

where, Φ_u is the unscattered energy fluence due to the head scatter photons and Φ_s is the energy fluence due to photons scattered by the wedge. With the attenuation factor of the wedge, A_w , Φ_u is given by

$$\Phi_u = A_w \Psi, \quad (6.5)$$

where Ψ is energy fluence incident on the wedge. For the energy fluence of any field with a wedge, we can get,

$$\Phi(X_c, Y_c, f) = \Phi(X_c, Y_c, f) \frac{\Phi(X_r, Y_r, f_r)}{\Phi(X_r, Y_r, f_r)}$$

$$= \Phi(X_r, Y_r, f_r) \frac{\Phi(X_c, Y_c, f)}{\Phi(X_r, Y_r, f_r)}, \quad (6.6)$$

where (X_c, Y_c, f) indicates collimator setting, $X_c \times Y_c$ with SDD of f , and

(X_r, Y_r, f_r) indicates a reference field with the collimator setting, $X_r \times Y_r$ with SDD of f_r . By substituting Eq. (6.4) into Eq. (6.6), we obtain

$$\Phi(X_c, Y_c, f) = \Phi(X_r, Y_r, f_r) \frac{\Phi_u(X_c, Y_c, f)}{\Phi_u(X_r, Y_r, f_r)} \frac{\left(1 + \frac{\Phi_s(X_c, Y_c, f)}{\Phi_u(X_c, Y_c, f)}\right)}{\left(1 + \frac{\Phi_s(X_r, Y_r, f_r)}{\Phi_u(X_r, Y_r, f_r)}\right)}. \quad (6.7)$$

Using the effective source position of open field, we have

$$\Phi_u(X_c, Y_c, f) = \left(\frac{f_r - v_0}{f - v_0}\right)^2 \Phi_u(X_c, Y_c, f_r), \quad (6.8)$$

where v_0 is the shift of source position for the open field, which is the same as v in Eq.

(6.3) and is determined by experiment (Tatcher & Bjärngård 1992, McKenzie & Stevens 1993). On the other hand, we can express

$$\Phi_s(X_c, Y_c, f) = \left(\frac{f_{wr} + w}{f_w + w}\right)^2 \Phi_s(X_c, Y_c, f_r) \quad (6.9)$$

for wedge scatter, where f_{wr} (or f_w) is the distance to the reference point (or point of measurement) from the wedge and w is the shift of source position of wedge scatter

radiation. Because the behavior of scatter source fits better into the inverse square law as the SDD increases, we may assume positive shift of w . Figure 6-1 schematically shows each parameter. In Figure 6-1, vw [same as v in Eq. (6.3)] is the shift of source position for wedge field in the one-effective-source method and should be distinguished from w .

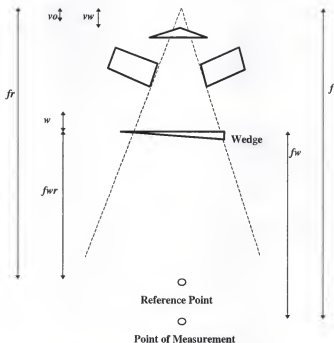


Figure 6-1. Schematic diagram showing the geometrical parameters. v_o and v_w indicate the shift of effective source position in 1 effective source method for open and wedge field, respectively. f_r (or f) is the distances from source to the reference point (or point of measurement) and f_{wr} (or f_w) is the distances from wedge to the reference point (or point of measurement).

By inserting Eq. (6.8) and (6.9) into Eq.(6.7), we have

$$\Phi(X_c, Y_c, f) = \Phi(X_r, Y_r, f_r) \left(\frac{f_r - v_0}{f - v_0} \right)^2 \frac{\Phi_u(X_c, Y_c, f_r)}{\Phi_u(X_r, Y_r, f_r)} \times \frac{\left(1 + \left(\frac{(f - v_0)(f_{wr} + w)}{(f_r - v_0)(f_w + w)} \right)^2 \frac{\Phi_s(X_c, Y_c, f_r)}{\Phi_u(X_c, Y_c, f_r)} \right)}{\left(1 + \frac{\Phi_s(X_r, Y_r, f_r)}{\Phi_u(X_r, Y_r, f_r)} \right)} \quad (6.10)$$

Using the definition of collimator scatter factor, S_c for open field and $S_{c,w}$ for wedged field, we can get

$$S_{c,w}(X_c, Y_c, f) = \left(\frac{f_r - v_0}{f - v_0} \right)^2 S_c(X_c, Y_c, f_r) \frac{\left(1 + \left(\frac{(f - v_0)(f_{wr} + w)}{(f_r - v_0)(f_w + w)} \right)^2 \alpha(X_c, Y_c) \right)}{(1 + \alpha_r)} \quad (6.11a)$$

with

$$\alpha(X_c, Y_c) = \frac{\Phi_s(X_c, Y_c, f_r)}{\Phi_u(X_c, Y_c, f_r)}, \quad (6.11b)$$

and

$$\alpha_r = \alpha(X_r, Y_r) = \frac{\Phi_s(X_r, Y_r, f_r)}{\Phi_u(X_r, Y_r, f_r)}, \quad (6.11c)$$

where α is defined as ratio of scatter fluence from wedge to unattenuated fluence.

Although the numerator accounts for the change in wedge scatter with field size, it actually includes the effect of field size dependence of head scatter. However, the field size dependence of head scatter is canceled by dividing it by the unattenuated fluence.

Therefore, α indicates the real field size dependence of wedge scatter. With a collimator scatter factor, $S_{C,w}(X_r, Y_r, f)$, for any point that is not on the reference SDD (i.e., $f \neq f_r$) for wedged field, Eq. (6.11a) gives α_r when w is known. Using α_r and two sets of standard dosimetric data, $S_C(X_C, Y_C, f_r)$ and $S_{C,w}(X_C, Y_C, f_r)$, a set of $\alpha(X_C, Y_C)$ is calculated. Once α_r and $\alpha(X_C, Y_C)$ are obtained, the collimator scatter factor at any field size and SDD, $S_{C,w}(X_C, Y_C, f)$, can be calculated by Eq. (6.11a). In practice, w is determined such that it gives the best agreement between calculated $S_{C,w}(X_C, Y_C, f)$ and experimental data.

When a tertiary collimator is used with an external wedge, the field size for the determination of wedge scatter is different from that for head scatter (see Figure 6-2). In Eq. (6.11a), $S_C(X_C, Y_C, f)$ is determined by the field size for head scatter and $\alpha(X_C, Y_C)$ is determined by the field size for wedge scatter.

Note that the last term of Eq. (6.11a) is a general wedge scatter factor at any SDD and becomes the same wedge scatter factor defined in the previous chapter (see Chapter 5) at $SDD = f_r$,

$$S_{ws}(X_C, Y_C) = \frac{\left(1 + \frac{\Phi_s(X_C, Y_C)}{\Phi_u(X_C, Y_C)}\right)}{\left(1 + \frac{\Phi_s(X_r, Y_r)}{\Phi_u(X_r, Y_r)}\right)} \quad (6.12)$$

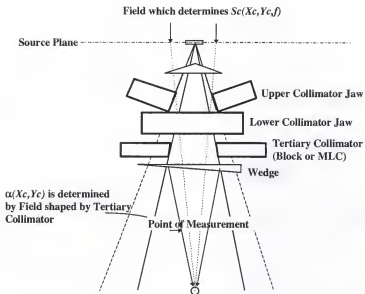


Figure 6-2. Schematic diagram showing the detector's eye view scatter area for head scatter and wedge scatter in external wedged field.

Methods and Materials

In this study w , the shift of source position of wedge scatter radiation is determined for a Varian 2100C linear accelerator. The Varian 2100C produces photon beams of 8 and 18 MV. An MLC is installed as a tertiary collimator. Four wedge filters, 15, 30, 45 and 60° wedges, can be inserted externally.

In-air output factor was measured with a cylindrical acrylic miniphantom as described by van Gasteren et al. (1991). The cylindrical phantom is 3.8 cm in diameter and 15 cm long. A shonka plastic 0.1 cm³ ionization chamber was inserted in the miniphantom with its center located at 5 cm for 8 MV and 10 cm for 18 MV from the front surface. Measurements were taken for square fields with SDD ranging from 80 to 130 cm. The collimator setting varied from 6 x 6 to 20 x 20 cm² (15 x 20 cm² for 60° wedge) at the isocenter with 15, 30, 45, and 60° wedges. Special care was taken to position the chamber on the central axis for measurements with wedge. Reversing the wedge direction did not change the measured readings by more than 0.4%. To obtain v_o , the shift of effective source for open field, in-air output factors of open fields were measured. Collimator settings of open field varied from 6 x 6 to 40 x 40 cm². For comparison, w , the shift of effective source in the one-effective-source method for wedge fields, was also determined. The values of v_o and w were extracted as the best fit to an inverse square dependence of the in-air output factor on distance.

To determine whether the algorithm is valid for a field in which the tertiary collimator shapes the irradiated area of wedge, in-air output factors of tertiary collimator

shaped fields were measured. Because wedge cannot be used with conventional blocks in a Varian machine that is equipped with MLC, only the MLC field was considered. The measurements were taken with the fixed X and Y collimator jaws ($20 \times 20 \text{ cm}^2$) for an 18 MV photon beam. The tertiary collimator varied from 6×6 to $14 \times 14 \text{ cm}^2$ for 45° wedge field (for convenience, square shapes were used instead of irregularly shaped fields). The SDDs varied from 80 to 130 cm.

Results

As in the literature (Tatcher & Bjärngård 1992, McKenzie & Stevens 1993), no systematic dependence of the effective source position on field size was observed. A $v_0 = 1.4 \text{ cm}$ for 8 MV and 1.1 cm for 18 MV photon beam was obtained. The magnitude of maximum relative differences $[100 \times (\text{calculated} - \text{measured}) / \text{measured}]$ between calculated in-air output factors using the inverse square law with the application of v_0 values and measurements was 0.3% for 8 MV and 0.5% for 18 MV through all field sizes (6×6 to $40 \times 40 \text{ cm}^2$) and all SDDs (80 - 130 cm). However, even without the application of effective source method ($v_0 = 0$), the maximum difference did not exceed 1%. Therefore, it may not be necessary to apply an effective source method for open field.

The shift of effective source position, w , of 15° , 30° , 45° , and 60° wedge fields is shown in Figure 6-3 for both 8 and 18 MV photon beams. Depending on field size and wedge angle, w ranged 1.8 - 9 cm for 8 MV and 2.3 to 8.6 cm for 18 MV. The values of w and corresponding maximum relative differences are tabulated in Table 6-1 for 8 MV

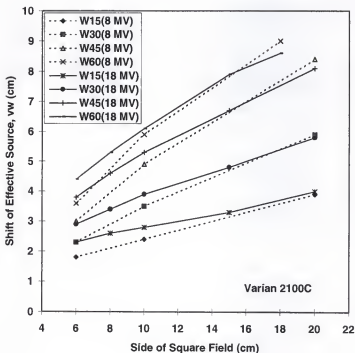


Figure 6-3. The shift of effective source position for wedged fields, w , in the one-effective-source method for 15, 30, 45, and 60° wedge fields of Varian 2100C with 8 and 18 MV photon beams. w is dependent on wedge angle, field size, and beam energy.

and Table 6-2 for 18 MV beam. The magnitude of difference was maximal (1.4% for both 8 and 18 MV) at the larger field size and higher wedge angle. For comparison, in-air output factors were also calculated using the inverse square law without applying an effective source method (i.e., $w = 0$), and relative differences of in-air output factors at SDDs of 80 and 130 cm are tabulated in Table 6-3 for 8 MV and Table 6-4 for 18 MV beam. Differences were maximal at 80 cm SDD in negative direction and at 130 SDD in positive direction. Without applying an effective source method, the magnitude of difference reached up to 6% at 80 cm SDD for a $15 \times 20 \text{ cm}^2$ field with 60° wedge for both 8 and 18 MV beams. As shown in Figure 6-3, w depends on wedge angle, field size, and beam energy. While w varies greatly according to wedge angle and field size, it does not change much between 8 and 18 MV energies.

The shift of effective source position of wedge scatter, w , was found to be independent of field size. No systematic dependency of w on either wedge angle or beam energy was observed. One value, $w = 7.5 \text{ cm}$, provided less than 1% difference in in-air output factors throughout the experimental ranges of 6×6 to $20 \times 20 \text{ cm}^2$ ($15 \times 20 \text{ cm}^2$ for a 60° wedge) field size, $15 - 60^\circ$ wedge angle, 80 to 130 cm SDD for both 8 and 18 MV photon beams. The differences among in-air output factors according to field size and SDD are given in Table 6-5 for a 45° wedge field with an 18 MV photon beam. For comparison, the differences among in-air output factors obtained by the one-effective-source method and the inverse square law without application of an effective source method are also tabulated in Tables 6-6 and 6-7, respectively. For illustration, the maximum difference in in-air output factors obtained by each method is plotted according

Table 6-1. The shift of effective source position, w (cm) in the one-effective-source method and maximum relative difference (%) of in-air output factor for 15, 30, 45, and 60° wedge fields with 18 MV photon beam of Varian 2100C. SDD ranges 80 - 130 cm. Relative difference is obtained by $100 \times (\text{calculated} - \text{measured}) / \text{measured}$.

Field Size	w (cm)				Max. Difference(%)			
	15°W	30°W	45°W	60°W	15°W	30°W	45°W	60°W
6x6	2.3	2.9	3.8	4.4	-0.4	-0.4	-0.6	-0.7
8x8	2.6	3.4	4.6	5.3	-0.5	-0.6	-0.8	-0.8
10x10	2.8	3.9	5.3	6.1	-0.5	-0.6	-0.9	-0.9
15x15	3.3	4.8	6.7	7.9	-0.6	-0.8	-1.2	-1.2
20x20*	4.0	5.8	8.1	8.6	-0.7	-1.0	-1.4	-1.4

* 15x20 for 60° wedge

Table 6-2. The shift of effective source position, w (cm) in the one-effective-source method and maximum relative difference(%) of in-air output factor for 15, 30, 45, and 60° wedge fields with 8 MV photon beam of Varian 2100C. SDD ranges 80 - 130 cm.

Field Size	w (cm)				Max. Difference(%)			
	15°W	30°W	45°W	60°W	15°W	30°W	45°W	60°W
6x6	1.8	2.3	3.0	3.6	-0.3	-0.4	-0.4	-0.6
10x10	2.4	3.5	4.9	5.9	-0.4	-0.6	-0.7	-1.1
20x20*	3.9	5.9	8.4	9.0	-0.6	-1.0	-1.2	-1.4

* 15x20 for 60° wedge

Table 6-3. The relative difference of in-air output factor according to field size at 80 and 130 SDDs for 15, 30, 45, and 60° wedge fields with 18 MV photon beam of Varian 2100C. In-air output factor is calculated by the inverse square law without application of an effective source method.

Field Size	Difference(%) at 80 SDD				Difference(%) at 130 SDD			
	15°W	30°W	45°W	60°W	15°W	30°W	45°W	60°W
6x6	-1.5	-1.9	-2.6	-2.9	0.7	1.0	1.2	1.5
8x8	-1.7	-2.3	-3.1	-3.6	0.8	1.1	1.4	1.8
10x10	-1.9	-2.6	-3.6	-4.1	0.9	1.2	1.7	2.1
15x15	-2.3	-3.3	-4.7	-5.4	1.0	1.5	2.1	2.7
20x20*	-2.8	-4.0	-5.7	-6.0	1.2	1.8	2.8	2.9

* 15x20 for 60° wedge

Table 6-4. The relative difference of in-air output factor according to field size at 80 and 130 SDDs for 15, 30, 45, and 60° wedge fields with 8 MV photon beam of Varian 2100C. In-air output factor is calculated by the inverse square law without application of an effective source method.

Field Size	Difference(%) at 80 SDD				Difference(%) at 130 SDD			
	15°W	30°W	45°W	60°W	15°W	30°W	45°W	60°W
6x6	-1.2	-1.5	-1.9	-2.4	0.6	0.8	1.2	1.2
10x10	-1.6	-2.4	-3.2	-4.1	0.8	1.1	1.8	1.9
20x20*	-2.5	-4.0	-5.6	-6.2	1.4	2.0	3.1	3.2

* 15x20 for 60° wedge

Table 6-5. The relative difference of in-air output factor according to field size and SDD for 45° wedge field with 18 MV photon beam of Varian 2100C. In-air output factor is calculated by the two-effective-source method, that is, Eq. (6.11) with $w = 7.5$ cm. To calculate α_r , $S_{c,w}(10,10,80)$ is used.

Field Size	Difference(%) at each SDD					
	80	90	100	110	120	130
6x6	0.4	0.4	0.0	-0.3	-0.5	-0.4
8x8	0.2	0.4	0.0	-0.3	-0.5	-0.4
10x10	0.0	0.3	0.0	-0.3	-0.5	-0.3
15x15	0.4	0.5	0.0	-0.3	-0.5	-0.5
20x20	0.6	0.5	0.0	-0.4	-0.7	-0.6

Table 6-6. The relative difference of in-air output factor according to field size and SDD for 45° wedge field with 18 MV photon beam of Varian 2100C. In-air output factor is calculated by the one-effective-source method.

Field Size	Difference(%) at each SDD					
	80	90	100	110	120	130
6x6	-0.7	0.2	0.0	-0.3	-0.6	-0.7
8x8	-0.8	0.2	0.0	-0.4	-0.7	-0.8
10x10	-0.9	0.2	0.0	-0.4	-0.8	-1.0
15x15	-1.2	0.2	0.0	-0.5	-0.8	-1.2
20x20	-1.4	0.2	0.0	-0.6	-1.1	-1.4

Table 6-7. The relative difference of in-air output factor according to field size and SDD for 45° wedge field with 18 MV photon beam of Varian 2100C. In-air output factor is calculated by the inverse square law without application of an effective source method.

Field Size	Difference(%) at each SDD					
	80	90	100	110	120	130
6x6	-2.6	-0.8	0.0	0.5	0.8	1.2
8x8	-3.2	-0.9	0.0	0.5	1.0	1.5
10x10	-3.7	-1.2	0.0	0.7	1.1	1.7
15x15	-4.7	-1.4	0.0	0.9	1.6	2.2
20x20	-5.7	-1.9	0.0	1.1	1.9	2.8

to field size in Figure 6-4 for a 45° wedge field with an 18 MV photon beam. In the inverse square method, the maximum difference dramatically increases as field size increases. The maximum difference for the one-effective-source method also increases by a significant amount with field size. However, the two-effective-source method showed very little dependence of maximum difference on field size. The differences among in-air output factors according to SDD are shown in Figure 6-5 for a 20 x 20 cm² field with a 45° wedge with an 18 MV photon beam. The two-effective-source method predicted in-air output factors accurately (less than 1% difference) through the whole range of SDDs (80 to 130 cm).

The differences among in-air output factors for 45° wedge fields for an 18 MV photon beam with a tertiary collimator (MLC) are presented in Table 6-8. The secondary

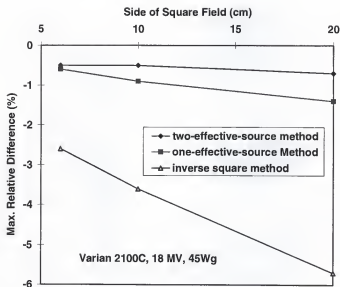


Figure 6-4. Maximum relative difference of in-air output factors according to field size for 45° wedge fields of Varian 2100C with 18 MV photon beam. In-air output factors are calculated by 3 different methods, inverse square method, one-effective-source method, and two-effective-source method.

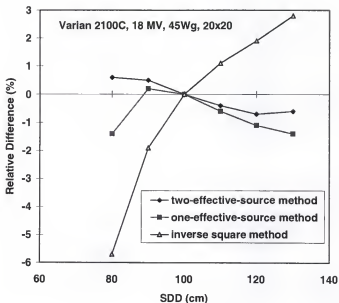


Figure 6-5. Relative difference of in-air output factors according to SDD for 20 x 20 field with 45° wedge of Varian 2100C at 18 MV photon beam. In-air output factors are calculated by 3 different methods, inverse square method, one-effective-source method, and two-effective-source method.

collimator was fixed as $20 \times 20 \text{ cm}^2$ during variation of the tertiary collimator. Because the field size for the determination of wedge scatter is different from that for head scatter, the one-effective-source method cannot be applied to this case. However, as shown in Table 6-8, the two-effective-source method accurately predicted the in-air output factor with a difference of less than 1 %. The field mapping method through the detector's eye view was used to calculate $S_c(X_c, Y_c, f_r)$ for the tertiary collimator field (see Chapter 5).

Table 6-8. The relative difference of in-air output factor according to MLC field size and SDD for 45° wedge field with 18 MV photon beam of Varian 2100C. Secondary collimator is set 20×20 . In-air output factor is calculated by the two-effective-source method, Eq. (6.11) with $w = 7.5 \text{ cm}$. To calculate α , $S_{c,w}(10,10,80)$ is used. S_c is calculated using field mapping method through detector's eye view.

MLC Field Size	Difference(%) at each SDD					
	80	90	100	110	120	130
6x6	-0.1	0.1	-0.3	-0.2	-0.5	-0.3
10x10	-0.3	0.0	-0.2	-0.2	-0.4	-0.3
14x14	-0.3	-0.1	-0.3	-0.4	-0.6	-0.4

Discussion

The parameter α is similar to scatter-to-primary ratio [see Eq. (6.11b)]. Whereas the numerator accounts for the change in wedge scatter with field size, the denominator

accounts for the change in head scatter. As illustrated in Eq. (6.12), $(1+\alpha)/(1+\alpha_r)$ becomes wedge scatter factor, S_{ws} , when $SDD = f_r$.

To determine f_{wr} (or f_w), the distance from wedge to the reference point (or point of measurement), the top of the wedge was chosen. Any point (middle or bottom of the wedge) can be chosen as the location of wedge. However, this does not change $f_{wr} + w$ (or $f_w + w$), the distance from the effective source of wedge scatter to the reference point (or point of measurement).

In Eq. (6.11a), α_r is obtained using the collimator scatter factor, $S_{c,w}(X_r, Y_r, f)$, of a point that is not on the reference SDD ($f \neq f_r$) for a wedged field. In Table 6-5, $S_{c,w}(10,10,80)$ was used to get α_r . Depending on which measurement data are used, the values of α_r and $\alpha(X_c, Y_c)$ may change. The same calculation as in Table 6-5 was accomplished with $S_{c,w}(10,10,130)$ and very similar results were obtained (Table 6-9).

Conclusion

A simple algorithm was developed for calculating the in-air output factor at various SDDs on the central axis for wedged fields. In the algorithm, two effective sources, one for head scatter and the other for wedge scatter, are dealt with independently. The effective source position of head scatter for wedged fields is the same

as for open fields. The effective source position of wedge scatter is assumed to be at certain distances upstream from the physical location of wedge. The shift of effective source of wedge scatter, w , is found to be independent of field size. Moreover, no systematic dependency of w on both wedge angle and beam energy was observed. One value, $w = 7.5$ cm, provided less than a 1% difference among in-air output factors through the whole experimental ranges, that is, 6×6 to 20×20 cm² (15×20 cm² for 60° wedge) field size, 15 - 60° wedge angle, 80 to 130 cm SDD, and both 8 and 18 MV photon beams. The algorithm is also valid when a tertiary collimator is used with an external wedge, in which field size for the determination of wedge scatter is different from that for head scatter.

Table 6-9. The relative difference of in-air output factor according to field size and SDD for 45° wedge field with 18 MV photon beam of Varian 2100C. In-air output factor is calculated by the two-effective-source method, Eq. (6.11) with $w = 7.5$ cm. To calculate α_r , $S_{c,w}(10,10,130)$ is used.

Field Size	Difference(%) at each SDD					
	80	90	100	110	120	130
6x6	-0.3	0.2	0.0	-0.1	-0.3	-0.2
8x8	-0.5	0.1	0.0	-0.2	-0.3	-0.1
10x10	-0.6	0.0	0.0	-0.2	-0.2	0.0
15x15	-0.3	0.3	0.0	-0.2	-0.2	-0.3
20x20	0.1	0.3	0.0	-0.3	-0.4	-0.3

CHAPTER 7 CONCLUSIONS

General Discussion

Irregular fields have historically been shaped by a tertiary collimator system. Conventionally Cerrobend blocks have been used as tertiary collimators. The in-phantom dosimetric parameters, such as the tissue-air-ratio (TAR) or tissue-maximum-ratio (TMR), and phantom scatter factor are calculated based on the actual field shape created by the custom Cerrobend block, but the in-air output factor (or collimator scatter factor) calculation is based on the rectangular field shaped by secondary collimator jaws, and is considered independent of any tertiary blocking. For irregular fields shaped with MLC, the method for in-air output factor calculation is dependent on the MLC design.

When a MLC is attached as a tertiary collimator below the secondary collimators, the method of in-air output factor calculation has been the same as the conventional method using Cerrobend blocks. However, there are three concerns with the conventional method. First, the effect of collimator exchange is not explicitly accounted if the conventional equivalent square field formula, that is, area-to-perimeter ratio formula (Sterling et al. 1964), is used to convert the rectangular field to the equivalent square field. Second, the effect of tertiary collimator is not considered. And finally, the effect of beam modifier (or wedge) is either overestimated or underestimated.

The in-air output factors of a $L \times W$ and a $W \times L$ rectangular field are not the same. The difference reaches 2 to 3% for open field (Moyer 1978, Kase & Svensson 1986, Tatcher & Bjärngård 1993) and 3 to 4% for wedged field (Tatcher & Bjärngård 1993). It increases with the elongation ratio. This effect is referred to as "collimator exchange effect". To account for the collimator exchange effect, an empirical formula (Vadash & Bjärngård 1993, Yu et al. 1995b) has been introduced. However, users have to carry out a large number of measurements to determine the weighting factor for the formula described in these publications.

When a tertiary collimator is used to form an irregular field, scatter contribution from the tertiary collimator may affect the in-air output factor, especially when the area of irregular field is too small compared to the collimator opening. In Chapter 5, in-air output factors were measured according to the tertiary collimator (Cerrobend block and Varian MLC) field size with the fixed secondary collimator openings using an 8 MV photon beam on a Varian 2100C. The results (see Figures 5-6 & 5-7) show that the in-air output factor increases at first (up to 1.5% for Cerrobend block field and 0.5% for MLC field), then decreases as the field size is decreased. Also shown in Figures 5-6 & 5-7 are the conventional in-air output factors which have a constant value (1.030 for block field and 1.028 for MLC field) for all field sizes. The results of this experiment indicate that the amount of scatter contribution from the tertiary collimator is not negligible.

The Varian MLC is an add-on device that is attached to the conventional linear accelerator head. Varian changed the location of the wedge to make enough room for MLC inside the head. The wedge is inserted below the MLC. This kind of wedge is

referred to as “external wedge”. When a wedge is located above the secondary collimator, a tertiary blocking does not change the area of wedge that is irradiated by the incident photon beam. However, if a wedge is located underneath the tertiary collimator, for example, in the case of a Varian MLC, the irradiated area of wedge changes according to the irregular shape formed by the MLC. Thus, the amount of scatter contribution from the wedge varies as the tertiary collimator field size changes. The conventional method of in-air output calculation cannot account for this effect and always overestimates wedge scatter contribution. Figure 5-9 shows the in-air output factor as a function of the MLC field size with a fixed secondary collimator opening for a 45° wedge field with an 8 MV photon beam on a Varian 2100C. While the conventional method predicts a constant value of output factor for all field sizes, experimental measurement shows that output continuously decreases as MLC field size decreases. These experiments show that the accurate prediction of output factor requires explicit accounting of collimator exchange effect, scatter from tertiary collimator, and scatter from beam modifiers.

The head scatter factor depends on head scattered radiation which can reach the detector. If any ray line of head scatter to the detector is blocked by tertiary collimator such as Cerrobend block or MLC, the head scatter factor is expected to decrease. Therefore, head scatter factor depends on the field size defined at the source (or flattening filter) plane through the detector’s eye view instead of the conventional field size defined at the detector (or isocenter) plane by the collimator jaw opening. The field defined by DEV is illustrated in Figure 5-2. To calculate the head scatter factor, the DEV field should be used. There are two ways of using the DEV field; (i) the method of

modeling the source distribution function and (ii) the field mapping method. In the first method, a source distribution function is set at the source (or flattening filter) plane. Head scatter factor is calculated by integrating the function over the DEV field. Several models have appeared in the literature that describe the scatter photon energy fluence distribution that emanates from the head. However, these model based approaches require sophisticated programming and/or complex measurements. Moreover, these studies have mainly concentrated on the modeling of scatter radiation from flattening filter, and are applicable only to open field. In the field mapping method developed in this study, a DEV field is mapped back into the detector plane by an equivalent field relationship at the source plane. For an irregular field, the field is segmented into sectors and each segmented DEV sector is mapped into an equivalent square field at the detector plane; and Clarkson integration is performed over the whole DEV field. There are two advantages of this method. One is that this method keeps parametrization at the detector plane. The other is that the user can easily choose the degree of comprehensiveness of standard dosimetry because the components that affect the in-air output factor are piecewise parameterized. For example, no new data is required to clinically implement this method if the field size dependence of monitor back scatter factor is insignificant and scatter from the tertiary MLC is negligible. In this case, the field size dependence of head scatter measured for a range of square field sizes is sufficient to implement this methodology. When more accurate treatment of monitor back scatter factor is needed, as is expected to be the case in beam intensity modulation therapy, the user can measure monitor back scatter factors and can explicitly account for it.

When an MLC replaces one set of the secondary collimators, the effect of MLC on the in-air output factor is much more prominent. The in-air output factors are determined by the actual irregular field shape instead of the rectangular field. Methods such as the conventional Clarkson calculation (Clarkson 1941) are often employed to determine the scatter from an irregular shaped field. Clarkson calculations make use of an equivalent square field and circular field relationship to determine the collimator scatter factor. Palta et al. (1996) used an equivalent square method to predict the collimator scatter factor for Philips MLC fields. In their method, an effective radius of an irregular field is obtained first, then, the circular field with the effective radius is converted to an equivalent square field using Day's formula (Day & Aird 1983). Although this method provides a simple methodology, it does not account for either the collimator exchange effect or the nonlinearity of in-air output dependency on field size.

In the Philips MLC, the MLC is the closest collimator to the source. If a set of collimator scatter factors is measured according to the square fields determined by only the MLC (i.e., dosimetry with a single-plane collimator) and lower collimator jaws are always positioned beyond or at the edge of the MLC field, it is not necessary to use the detector's eye view approach. In this case the DEV field and the conventional field at the detector plane are directly proportional (i.e., there is no collimator exchange effect). Therefore, Clarkson integration can be carried out directly over the conventional field. When the MLC replaces the lower collimator jaws, the collimator exchange effect still exists. Furthermore, the secondary trimmer should be considered during the DEV field

determination on a GE MLC because in their design the trimmer is the closest collimator system to the source.

Conclusions

The conclusions of the present research are as follows:

1) Development of MLC module

The use of MLC has significantly increased. There are three major advantages of using an MLC. At first, since the field shaping is done using the leaves, the fabrication of custom block is no longer needed. This increases the treatment delivery efficiency because multiple fields can be treated in a short time without reentering the treatment room. The second is that all problems associated with heavy blocks, alterations, remodeling and remounting can be eliminated. The third advantage is in the future use of this technology for the delivery of 3-D conformal therapy and intensity modulated radiation therapy.

In Chapter 2, an MLC geometric optimization and user interface module was developed. The MLC module was implemented on a main RTTP system, ROCS (version 5.1.1) and is used clinically in many clinical sites worldwide. The incorporation of the MLC module into the main RTTP system significantly reduced the planning time.

2) In-air output factor calculation method

To solve the problem of the collimator exchange effect, a simple formula was derived for the calculation of an equivalent square field that gives the same head scatter factor as a given rectangular field (Chapter 4). This formula is based strictly on the configuration of a medical linear accelerator treatment head. The geometric parameters used in this formula are the distances between the target and the top of each field-defining aperture. The formula accounts for both the effect of field elongation and the collimator exchange effect. This method predicts the output to within 1% accuracy for both open and wedge fields and does not require any new measured data other than the field size dependence of head scatter for a range of square field sizes.

In Chapter 4, the study was limited to rectangular fields only. A generalized solution for in-air output factor calculation was introduced in Chapter 5. Three major scatter contributors to the in-air output of a medical linear accelerator are flattening filter, wedge, and tertiary collimator. These were considered separately in the development of the algorithm which was used to set up an in-air output factor calculation formalism for irregular shaped open and wedge fields. A detector's eye view field defined at the source plane is used to account for the effects of collimator exchange and the partial blockage of flattening filter by tertiary collimator in the determination of head scatter. An irregular field determined at the source plane by detector's eye view is segmented and mapped back into the detector plane by field mapping method. Field mapping is performed by using geometric conversion factor and equivalent field relationships for head scatter. Scatter contribution of each segmented equivalent field at the detector plane is summed

by Clarkson integration. Same methodology is applied for determining both tertiary collimator and wedge scatter contribution. However, the field size which determines the amount of scatter contribution is not the same for each component. For tertiary collimator scatter, a field projected to the detector plane is directly used. While a detector's eye view field at the source plane is used to determine the amount of wedge scatter when wedge is located above the secondary collimator, a field projected at the detector plane is used if wedge is below the tertiary collimator (e.g., external wedge). Comparisons of the in-air output factors between calculated and measured values show a good agreement for both open and external wedge fields. This algorithm can be used for MLC fields irrespective of the position of MLC (i.e., whether an MLC replaces one of secondary collimator or is used as a tertiary collimator). The measurement and parametrization of tertiary collimator scatter is necessary to account for tertiary collimator scatter contribution to the in-air output. Because a source plane field is mapped into the detector plane, no additional dosimetric data acquisition is necessary for the calculation of head scatter.

An equivalent field relationship is necessary to apply the field mapping method in the derivation of the generalized in-air output factor calculation algorithm. In Chapter 3, an equivalent field relationship between square and circular fields for head scatter factor was evaluated at the source plane. The method is based on integrating the head scatter parameter for projected shaped fields in the source plane and finding a field that produces the same ratio of head scatter to primary dose on the central axis. A value of $\sigma/R \cong 0.9$ is obtained, where σ is one half of the side length of the equivalent square and R is the radius of the circular field. The assumptions are that the equivalent field relationship for

head scatter depends primarily on the characteristics of scatter from the flattening filter, and that the differential scatter-to-primary ratio of scatter from the flattening filter decreases linearly according to the radius within the physical radius of the flattening filter. It is empirically shown in a literature (Lam et al. 1996) that when the area-to-perimeter ratio formula is applied to an equivalent square formula at the flattening filter plane, it gives accurate prediction of head scatter factor. The validity of the area-to-perimeter ratio formula was analytically investigated. The result supports the area-to-perimeter ratio formula of the equivalent field for head scatter at the source plane. The equivalent field relationships for wedge and tertiary collimator scatter were also evaluated. The relationships of $\sigma = 0.886 R$ for a circular field and $\sigma = \sqrt{LW} / 2$ for a $L \times W$ rectangular field were obtained.

In megavoltage photon therapy, it has been generally assumed that in-air output at central axis varies proportional to the inverse square of SDD. In a megavoltage linear accelerator, the physical source of x-rays lies at the site where the electron beam hits the target. As the photons move forward, they pass through other structures in which they may undergo scattering interactions. Depending on the structure and collimator system, different amount of scattered photons can reach the point of measurement. Therefore, one can expect that the contribution of scattered photons will produce a downstream shift in the location of the effective x-ray source (Tatcher & Bjärngard 1992). One would expect that the increased scatter from an external wedge will move the effective source position further downstream from the target and that the position is highly field size dependent. Moreover, when a tertiary collimator is used with an external wedge, a field

size for the determination of wedge scatter is different from that for head scatter (see Chapter 5). A simple algorithm for the calculation of in-air output factors at various SDDs on central axis for wedged fields was developed in Chapter 6. In the algorithm, two effective sources, one for head scatter and the other for wedge scatter, were dealt with independently. The effective source position of head scatter for wedged fields is the same as for open fields. The effective source position of wedge scatter is assumed to be at a certain distance upstream from the physical location of wedge. It is found that the shift of effective source of wedge scatter, w is independent of field size. Moreover, no systematic dependency of w on both wedge angle and beam energy was observed. One value of $w = 7.5$ cm provided less than 1% difference of in-air output factors. This algorithm is also valid when a tertiary collimator is used with an external wedge, and in which a field size for the determination of wedge scatter is different from that for head scatter.

3) Future work

One of the more exciting applications of MLC is the delivery of intensity modulated radiation field. Many methods of beam delivery for intensity modulation have been developed (Källman et al. 1988, Convery & Rosenbloom 1992, Bortfeld et al. 1994, Yu et al. 1995a). In these techniques, the field sizes used are relatively smaller than the fields used in conventional therapy. Therefore, on a Varian MLC, small MLC fields with a large secondary collimator opening may be used. The conventional method of calculating the in-air output factor is expected to be inaccurate. Accurate calculations will require explicit accounting of the combined effect of MLC and secondary collimator

on both the central axis and off-axis points. In this study, the in-air output factor calculation method has been restricted to central axis. However, the generalized in-air output factor calculation method can be easily expanded to off-axis fields. This issue will be an important subject for future research.

APPENDIX A SOURCE PROGRAM OF THE MLC MODULE

The following computer program was written in BASIC to provide MLC module for ROCS treatment planning system. Each subroutine contains the description of subroutine. Variables are also explained in the heading comment. This program has been implemented for ROCS version 5.1.1 and is in clinical use at many clinic sites worldwide.

```

* SUBROUTINE:
*   MLCINI ()
*
* SYNOPSIS:
*   INCLUDE comrocs.inc
*   INCLUDE comstr.inc
*   INCLUDE comstr1.inc
*   INCLUDE comstr3.inc
*   INCLUDE comstr6.inc
*   INCLUDE comstr7.inc
*
SUB MLCINI STATIC
1000
*
* DESCRIPTION:
*   This subroutine specify MLC dimension and set main variables
*
* ASSUMPTIONS:
*   This subroutine assumes valid input variables.
*
* GLOBAL_VARIABLES:
*   HLEAFNUM!  I 1/2 of number of leaves
*   LEAFCOLR!  I Color for MLC leaf
*   LEAFLEN!   O Length of MLC leaf
*   LEAFNUM!   O Number of leaves in one side (26 for Varian, 40 for Philips)
*   LEAFWD!    O Width of MLC leaf
*   MAXMLCDIF! I Max. of difference among leaves
*   MAXMLCFLD! I Max. of MLC field size in one side
*   MBAXIS!    I Lower left Y world coordinate for MLC field
*   MINMLCFLD! I Max. of leaf stretch to opposite side
*   MLAXIS!    I Lower left X world coordinate for MLC field
*   MLCMAG!    O Mag. for projection of MLC from 100cm to surface
*   MLCATYPE!  O Type of MLC (1 = Varian, 2 = Philips)
*   MRAXIS!    I Upper right X world coordinate for MLC field
*   MTAXIS!    I Upper right Y world coordinate for MLC field
*   NOTECOLR!  I Color for selected MLC leaf during manual MLC editing
*   SSDSAD!    O SSD/SAD distance (cm)
*   SSDSADMODE I Mode of setup (0 = SSD beam, 1 = SAD beam)
*
* FILES_USED:
*   None

```

```

SUBROUTINES_CALLED:
  LEAFINI Set initial values for leaf position
.
.
AUTHOR:
  Siyong Kim
.
REVISION_HISTORY:
.
=====
!
!===== DIMENSION SPECIFICATION =====
IF MLCATYPE = 1 THEN      !Varian Type MLC
  LEAFLEN=16.0           !LEAF LENGTH
  LEAFWID=1.0            !LEAF WIDTH
  LEAFNUM=26             !# OF LEAF FOR EACH SIDE
ELSEIF MLCATYPE = 2 THEN  !Philips Type MLC
  ELSE
  END IF
!===== GET MAGNIFICATION FACTOR =====
MLCMAG= 1 !
IF SSDSADMODE = 0 THEN
  MLCMAG= SSDSAD/*0.0!
END IF

!===== PROJECT LEAF DIMENSION FROM 100cm TO SURFACE =====
LEAFLEN=LEAFLEN*MLCMAG!
LEAFWID=LEAFWID*MLCMAG!
!===== SET MAIN VARIABLES =====
MAXMLCFLD=20.0*MLCMAG! MAX. OF MLC FIELD SIZE IN ONE SIDE
MINMLCFLD=16.0*MLCMAG! MAX. OF LEAF STRETCH TO OPPOSITE SIDE
MAXMLCDIF=14.5*MLCMAG! MAX. OF DIFFERENCE BETWEEN LEAVES
HLEAFNUM=0.5*LEAFNUM
LEAFCOLR=14             !LEAF COLOR
NOTECOLR=3              !SELECTED LEAF COLOR
HCURCOLR=4              !CROSSHAIR CURSOR COLOR
HCURDIM=0.5             !CROSSHAIR CURSOR DIMENSION

CALL LEAFINI             !SET INITIAL LEAF POSITION
END SUB

!=====
SUBROUTINE:
  MLCDRAW ()
.
.
SYNOPSIS:
  INCLUDE comres.inc
  INCLUDE comir7.inc
.
SUB MLCDRAW STATIC
1100
.
DESCRIPTION:
  This subroutine draws MLC leaves with leaf position data
.
.
ASSUMPTIONS:
  This subroutine assumes valid input variables.
.
GLOBAL_VARIABLES:
  AXDATA(I)  I X-coordinate data of leaf A
  AXDATAS(I) I X-coordinate data of leaf A for display on screen
  AYDATA(I)  I Y-coordinate data of leaf A
  AYDATAS(I) I Y-coordinate data of leaf A for display on screen
  BAXIS!     I Lower left Y world coordinate
  BXDATA(I)  I X-coordinate data of leaf B
  BXDATAS(I) I X-coordinate data of leaf B for display on screen
  BYDATA(I)  I Y-coordinate data of leaf B
  BYDATAS(I) I Y-coordinate data of leaf B for display on screen
  CA!        O Cosine value of collimator angle
  CLROLD     I Original color index for graphics
  LAXIS!     I Lower left X world coordinate
  LEAFCOLR   I Color for MLC leaf

```

```

      LEAFNUM      O Number of leaves in one side (26 for Varian, 40 for Philips)
      SA!          O Sine value of collimator angle

      FILES_USED:
      None

      SUBROUTINES_CALLED:
      INQCLR       HALO, inquire color index at (X,Y)
      ISODRW       Draws original isocenter before MLC offset
      MOVABS       HALO, move graphics cursor to (X,Y)
      POLYNABS     HALO, draw a polygon specified by absolute points
      SETCOLOR     HALO, set active color

      AUTHOR:
      Siyong Kim

      REVISION_HISTORY:

      [=====]
      |
      |===== GET POSITION ON SCREEN BY CONVERTING WITH ANGLE =====|
      J=LEAFNUM-1
      FOR I=0 TO J
        FOR K=0 TO 4
          AXDATAS(K,I)=AXDATA(K,I)*CA!-AYDATA(K,I)*SA!
          AYDATAS(K,I)=AYDATA(K,I)*CA!+AXDATA(K,I)*SA!
          BXDATAS(K,I)=BXDATA(K,I)*CA!-BYDATA(K,I)*SA!
          BYDATAS(K,I)=BYDATA(K,I)*CA!+BXDATA(K,I)*SA!
        NEXT K
      NEXT I

      |===== DRAW MLC ON SCREEN =====|
      CALLS INQCLR(LAXIS!, BAXIS!, CLROLID)
      CALLS SETCOLOR(LEAFCOLR)

      J=LEAFNUM-1
      FOR I=0 TO J
        CALLS MOVABS(BXDATAS(I,I),BYDATAS(I,I))
        CALLS POLYNABS(BXDATAS(I,I),BYDATAS(I,I),5)

        CALLS MOVABS(AXDATAS(I,I),AYDATAS(I,I))
        CALLS POLYNABS(AXDATAS(I,I),AYDATAS(I,I),5)
      NEXT I
      CALLS SETCOLOR(CLROLID)
      |===== DRAW ISOCENTER BEFORE OFFSET =====|
      CALL ISODRW
      END SUB
      [=====]
      |
      | SUBROUTINE:
      | MLCOPT()
      |
      | SYNOPSIS
      | INCLUDE comir inc
      | INCLUDE comar? inc
      |
      SUB MLCOPT STATIC
      1200
      |
      | DESCRIPTION.
      | This subroutine search geometrically optimized MLC leaf position
      |
      | ASSUMPTIONS:
      | This subroutine assumes valid input variables.
      |
      | GLOBAL_VARIABLES.
      | AXDATA(I)      I X-coordinate data of leaf A
      | AYDATA(I)      I Y-coordinate data of leaf A
      | BXDATA(I)      I X-coordinate data of leaf B
      | CA!            O Cosine value of collimator angle
      | CCWX(I)        O Temporary X-coord for field outline rotated

```

```

      opposite to collimator rotation
      CCWY(I)  O Temporary Y-coord. for field outline rotated
      opposite to collimator rotation
      CONTSHIFTX I MLC offset in X-dir. (cm)
      CONTSHIFTY I MLC offset in Y-dir. (cm)
      DIFF I O Difference between longest leaf and each one
      OY I O Difference in Y between two consecutive vertices (cm)
      FLOEDGE I Irregular field outline coordinates (cm*100)
      FLDMAXVER I O Highest point of outline in vertical direction
      FLOMINVER I O Lowest point of outline in vertical direction
      FLOPTNUM I Number of vertices in field outline
      GRA I O Gradient between two vertices
      LA(I) O Temporary leaf position in side A
      LADIFF I O Difference between most right and most left leaves in side A
      LAMINUS I O Most left leaf position in side A
      LAPLUS I O Most right leaf position in side A
      LB(I) O Temporary leaf position in side B
      LBDIFF I O Difference between most right and most left leaves in side B
      LBMINUS I O Most left leaf position in side A
      LBPLUS I O Most right leaf position in side A
      LEAPLEN I O Length of MLC leaf
      LEAFNUM I O Number of leaves in one side (26 for Varian, 40 for Philips)
      LEAPWID I O Width of MLC leaf
      MAXMLCDIF I Max. of difference among leaves
      MAXMLCFLD I Max. of MLC field size in one side
      MINMLCFLD I Max. of leaf stretch to opposite side
      MLAXIS I I Initial A leaf position before optimization process
      MAXMLCDIF I I Max. of difference among leaves
      MRAXIS I I Initial B leaf position before optimization process
      OPTERRFLAG I O Indicate type of error during optimization
      SA I O Sine value of collimator angle
      XMAG(I) O X-coord. for field outline with offset (cm)
      XORG I O Original X-coord. for field outline (cm)
      XPARA I O Optimized leaf position during optimization process
      YMAG(I) O Y-coord. for field outline with offset (cm)
      YMID I O Y-coord. at mid point for each leaf (cm)
      YORG I O Original Y-coord. for field outline (cm)

      FILES_USED:
      None

      SUBROUTINES_CALLED
      CONVERTANG Convert collimator angle in degree to radian
      and get sine, cosine values

      AUTHOR:
      Siyoung Kim

      REVISION_HISTORY:

      =====
      !
      DIM LA(0 TO LEAFNUM-1), LB(0 TO LEAFNUM-1), CCWX(0 TO FLOPTNUM+1), CCWY(0 TO FLOPTNUM+1)
      CALL CONVERTANG

      FOR I=0 TO FLOPTNUM
        XORG=FLOEDGE(I,0)*0.01 XORG: ORIGINAL CONTOUR DATA
        YORG=FLOEDGE(I,1)*0.01
        XMAG(I)=XORG+CONTSHIFTX
        YMAG(I)=YORG+CONTSHIFTY YMAG: SHIFTED
        CCWX(I)=XMAG(I)*CA+YMAG(I)*SA CCWX: ROTATED IN CCW DIRECTION
        CCWY(I)=YMAG(I)*CA-XMAG(I)*SA
      NEXT I
      !===== ENSURE CLOSED CURVE =====
      CCWX(FLDPTNUM+1)=CCWX(0)
      CCWY(FLDPTNUM+1)=CCWY(0)
      !===== INITIAL LEAF POSITION =====
      MLAXIS=-40
      MRAXIS=40

      J=LEAFNUM-1

```

```

FOR I=0 TO J
  LA(I)=MLAXIS!
  LB(I)=MRAXIS!
NEXT I
FOR I=0 TO FLDPTNUM
  DY!=CCWY(I+1)-CCWY(I)
  IF DY! > 0.0 THEN
    FOR J=0 TO LEAFNUM-I
      ===== MIDDLE POSITION OF EACH LEAF =====
      YMID! = AYDATA(0,J) + 0.5*LEAFWID!
      IF YMID! >= CCWY(I) AND YMID! <= CCWY(I+1) THEN
        GRA!=(CCWY(I+1)-CCWY(I))/(CCWY(I+1)-CCWY(I))
        XPARA!=(GRA*(YMID-CCWY(I))+CCWY(I))
        IF XPARA! > LA(I) THEN
          LA(I)=XPARA!
        END IF
        IF XPARA! < LB(I) THEN
          LB(I)=XPARA!
        END IF
      END IF
    NEXT J
  END IF

  IF DY! < 0.0 THEN
    FOR J=0 TO LEAFNUM-I
      ===== MIDDLE POSITION OF EACH LEAF =====
      YMID! = AYDATA(0,J) + 0.5*LEAFWID!
      IF YMID! <= CCWY(I) AND YMID! >= CCWY(I+1) THEN
        GRA!=(CCWY(I+1)-CCWY(I))/(CCWY(I+1)-CCWY(I))
        XPARA!=(GRA*(YMID-CCWY(I))+CCWY(I))
        IF XPARA! > LA(I) THEN
          LA(I)=XPARA!
        END IF
        IF XPARA! < LB(I) THEN
          LB(I)=XPARA!
        END IF
      END IF
    NEXT J
  END IF

  IF DY! = 0.0 THEN
    FOR J=0 TO LEAFNUM-I
      ===== MIDDLE POSITION OF EACH LEAF =====
      YMID! = AYDATA(0,J) + 0.5*LEAFWID!
      IF YMID! = CCWY(I) THEN
        XPARA!=(CCWY(I))
        IF XPARA! > LA(I) THEN
          LA(I)=XPARA!
        END IF
        IF XPARA! < LB(I) THEN
          LB(I)=XPARA!
        END IF
      END IF
    NEXT J
  END IF
NEXT I

===== ADJUST THE ZEROS =====
J=LEAFNUM-I
FOR I=0 TO J
  IF LA(I)=MLAXIS! THEN
    LA(I)=0.0
  END IF
  IF LB(I)=MRAXIS! THEN
    LB(I)=0.0
  END IF
NEXT I

===== RESTRICTION CHECK AND FIT TO LIMIT VALUE =====
===== HORIZONTAL FIELD SIZE =====
J=LEAFNUM-I
FOR I=0 TO J

```

```

IF LA(I) > MAXMLCFLD THEN
  LA(I) = MAXMLCFLD
  OPTERRFLAG = -77
END IF
IF LA(I) < -MINMLCFLD THEN
  LA(I) = -MINMLCFLD
  OPTERRFLAG = -77
END IF
IF LB(I) > MINMLCFLD THEN
  LB(I) = MINMLCFLD
  OPTERRFLAG = -77
END IF
IF LB(I) < -MAXMLCFLD THEN
  LB(I) = -MAXMLCFLD
  OPTERRFLAG = -77
END IF
NEXT I

===== VERTICAL FIELD SIZE =====
MLCMAXVER! = HLEAFNUM! * LEAFWID!
FLDMAXVER! = CCWY(0)
FLDMINVER! = CCWY(0)
FOR I = 0 TO FLDFTNUM
  IF CCWY(I) > FLDMAXVER! THEN
    FLDMAXVER! = CCWY(I)
  END IF
  IF CCWY(I) < FLDMINVER! THEN
    FLDMINVER! = CCWY(I)
  END IF
NEXT I
IF FLDMAXVER! > MLCMAXVER! OR FLDMINVER! < -MLCMAXVER! THEN
  IF OPTERRFLAG = -77 THEN
    OPTERRFLAG = -99
  ELSE
    OPTERRFLAG = -88
  END IF
END IF
IF FLDMINVER! > MLCMAXVER! OR FLDMAXVER! < -MLCMAXVER! THEN
  OPTERRFLAG = -100
END IF

===== CHECK MAX DIFFERENCE AMONG LEAVES =====
J = LEAFNUM - 1
LAPLUS! = LA(0)
LAMINUS! = LA(0)
LBPLUS! = LB(0)
LBMINUS! = LB(0)
FOR I = 1 TO J
  IF LA(I) > LAPLUS! THEN
    LAPLUS! = LA(I)
  END IF
  IF LA(I) < LAMINUS! THEN
    LAMINUS! = LA(I)
  END IF
  IF LB(I) > LBPLUS! THEN
    LBPLUS! = LB(I)
  END IF
  IF LB(I) < LBMINUS! THEN
    LBMINUS! = LB(I)
  END IF
NEXT I
LADIFF! = LAPLUS! - LAMINUS!
LBDIFF! = LBPLUS! - LBMINUS!
IF LADIFF! > MAXMLCDIF! OR LBDIFF! > MAXMLCDIF! THEN
  IF OPTERRFLAG = -77 THEN
    OPTERRFLAG = -377
  
```

```

ELSEIF OPTIERRFLAG = -88 THEN
  OPTIERRFLAG = -388
ELSEIF OPTIERRFLAG = -99 THEN
  OPTIERRFLAG = -399
ELSEIF OPTIERRFLAG = -100 THEN

  ELSE
    OPTIERRFLAG = -33
  END IF
END IF

IF LADIFF! > MAXMLCDIF! THEN
  FOR I = 0 TO J
    DIFF! = LAPLUS! - LA(I)
    IF DIFF! > MAXMLCDIF! THEN
      LA(I) = LAPLUS! - MAXMLCDIF!
    END IF
  NEXT I
END IF
IF LBDIFF! > MAXMLCDIF! THEN
  FOR I = 0 TO J
    DIFF! = LB(I) - LBMINUS!
    IF DIFF! > MAXMLCDIF! THEN
      LB(I) = LBMINUS! + MAXMLCDIF!
    END IF
  NEXT I
END IF

***** ASSIGN THE OPTIMIZED POSITION TO LEAF DATA *****
FOR I=0 TO LEAFNUM-1
  AXDATA(I,0)=LA(I)
  AXDATA(I,1)=LA(I)+LEAFLEN!
  AXDATA(I,2)=LA(I)+LEAFLEN!
  AXDATA(I,3)=LA(I)
  AXDATA(I,4)=LA(I)

  BXDATA(I,0)=LB(I)
  BXDATA(I,1)=LB(I)-LEAFLEN!
  BXDATA(I,2)=LB(I)-LEAFLEN!
  BXDATA(I,3)=LB(I)
  BXDATA(I,4)=LB(I)
NEXT I
ERASE LA!, LB!, CCWX!, CCWY!

```

END SUB

```

=====
* SUBROUTINE:
*   MANOPTI 0
*
* SYNOPSIS:
*   INCLUDE comrocs.inc
*   INCLUDE comr7.inc
*
SUB MANOPTI STATIC
1300
*
* DESCRIPTION:
*   This subroutine enables manual MLC field editing
*
* ASSUMPTIONS:
*   This subroutine assumes valid input variables.
*
* GLOBAL VARIABLES:
*   AXDATA(I)   I X-coordinate data of leaf A
*   AYDATA(I)   I Y-coordinate data of leaf A
*   CA!         O Cosine value of collimator angle
*   CHCS(I)     I An array of character strings which make up main menu
*   CONTSHPITX! I MLC offset in X-dir. (cm)
*   CURX!       O Current X of selected leaf
*   CURXS!      O Current X of selected leaf for display on screen
*   CURY!       O Current Y of selected leaf

```

```

* CURYS!      O Current Y of selected leaf for display on screen
* INCR!       O Increment for leaf change at each step
* LEAFID      O Current leaf ID selected
* MLCOPTMODE  I Indicate type of fit (1=auto/2>manual)
* OLDSHIFTX!  I MLC offset in X-dir. (cm)
* ROW        I Index for first row in menu box
* SIDES       O Indicates current leaf side (A or B)
* SA!        O Sine value of collimator angle
* XORMODE     I Rubber band mode on/off
*
*
* FILES_USED:
*   None
*
* SUBROUTINES_CALLED
*   CONVERTANG  Convert collimator angle in degree to radian
*               and get sine, cosine values
*   DELHCUR    HALO, delete the crosshair cursor
*   DISDATA    Display isodose/phantom headings and data
*   DRWFLD     Draw field outline and MLC
*   KYB ALLKeysOFF Remove all key masks - accept no events
*   KYB ARROWKeysON Enable the arrow keys (UP, DN, LT, RT)
*   KYB ESCKeyON  Enable the escape key (ESC)
*   KYB KeyON     Enable a single key
*   KYB.KeyPolls  Listen to the keyboard event queue, return
*               a token representation of all accepted events,
*               Apply key masks, interpret special keystrokes.
*   KYB.RETKeyON  Enable the return key (RET)
*   LEAFDN      Select lower leaf during manual fit
*   LEAFLT      Move leaf to left during manual fit
*   LEAFRT      Select lower leaf during manual fit
*   LEAFUP      Move leaf to right during manual fit
*   MENUCLR     Clear menu display section
*   MPLDDATA    Get collimator opening and field outline for MLC field
*   MOVHCURABS  HALO, move crosshair cursor to (X,Y)
*   NOTELEAF    Assign different color to selected leaf
*               during leaf change in same side
*   NOTE2LEAF   Assign cursor and different color to selected leaf
*               during side change
*   REDRAWMLC   Redraw the changed leaf during manual fit
*   SETXOR      HALO, set rubberband mode
*
*
* AUTHOR:
*   Siyong Kim
*
* REVISION_HISTORY:
*
*
* {=====
*
* INCR = .5
* SIDES = "A"
* LEAFID = 13
* CHCS(0) = "MANUAL FIT"
* CALL MENUCLR
*
* LOCATE ROW + 1, 42
* PRINT "Use "; CHR$(27); " "; CHR$(26); " to move leaf edge. ";
* LOCATE ROW + 2, 42
* PRINT "Use "; CHR$(24); " "; CHR$(25); " to select leaf "; "("; LEAFID; ")."
* LOCATE ROW + 3, 42
* PRINT "Use F1 to choose leaf side ("; SIDES; ")."
* LOCATE ROW + 4, 42
* PRINT USING "&#401"; "Use * / to INC/DEC increment ("; INCR; ").";
* XORMODE = 1
* ===== SET INITIAL CURSOR POSITION =====
* CALL NOTELEAF
* CURX:=AXDATA(0,LEAFID-1)
* CURY:=0.5*(AYDATA(0,LEAFID-1)+AYDATA(3,LEAFID-1))
* CURXS:=CURX+"CA"-CURY+"SA"

```

```

CURYS:=CURY!*CA)+CURX!*SA)
CALLS INTHCUR(HCURDIM1, HCURDIM1, HCURCOLR)
CALLS MOVHCURABS(CURXS1, CURYS1)
LOCATE ROW, 3
PRINT USING "LEAF POSITION: <+## ##>"; CURX1

```

```

CALL KYB.ARROWKeyON
CALL KYB.ESCKeyON
CALL KYB.RETKeyON
CALL KYB.KeyON("F1")
CALL KYB.KeyON("F2")
CALL KYB.KeyON("F3")

```

DO

```
LOCATE ROW, 10
```

```
'***** User input *****'
```

```
SELECT CASE KYB.KeyPoll5
```

```

CASE "ESC"
EXIT DO

```

```

CASE "RET"
CALL REDRAWMLC
CONTSHIFTX:=OLDSHIFTX1

```

```

CASE "F1"
IF SIDES = "A" THEN
SIDES = "B"
ELSE
SIDES = "A"
END IF
LOCATE ROW + 3, 69
PRINT "C: SIDES: "; SIDES
CALL NOTE2LEAF

```

```

CASE "UP"
XORMODE=1
CALLS SETXOR(XORMODE)
CALL LEAFUP

```

```

CASE "DN"
XORMODE=1
CALLS SETXOR(XORMODE)
CALL LEAFDN

```

```

CASE "LT"
XORMODE=1
CALLS SETXOR(XORMODE)
CALL LEAFLT

```

```

CASE "RT"
XORMODE=1
CALLS SETXOR(XORMODE)
CALL LEAFRT

```

```

CASE "F4"
IF INCR1 = 81 THEN
OS.Sound 1046, 1
ELSEIF INCR1 = 11 THEN
INCR1 = 25
ELSE
INCR1 = INCR1 + 21
END IF
LOCATE ROW + 4, 71
PRINT USING "(###)"; INCR1;

```

```

CASE "F5"
IF INCR1 = 11 THEN
OS.Sound 1046, 1
ELSEIF INCR1 = 25 THEN
INCR1 = 11
ELSE

```

```

        INCR! = INCR! * .5
    END IF
    LOCATE ROW + 4, 71
    PRINT USING "(# #)"; INCR!

    ENO SELECT
LOOP

CALL KYB.ALLKeysOFF
CALLS DELHCUR
XORMODE = 0
MLCOPTMODE=1
CALL MFLDOATA
CALL DRWFLD
CALL OISOATA

ENO SUB
=====
' SUBROUTINE:
' LEAFLT ()
'
' SYNOPSIS:
' INCLUDE comar.inc
' INCLUDE comar?.inc
'
SUB LEAFLT STATIC
1400
'
' DESCRIPTION:
' This subroutine move leaf to left direction during manual fit
'
' ASSUMPTIONS:
' This subroutine assumes valid input variables
'
' GLOBAL_VARIABLES.
' AXDATA() 1 X-coordinate data of leaf A
' BXDATA() 1 X-coordinate data of leaf B
' CA!      0 Cosine value of collimator angle
' CURX!    0 Current X of selected leaf
' CURXS!   0 Current X of selected leaf for display on screen
' CURY!    0 Current Y of selected leaf
' CURY$!   0 Current Y of selected leaf for display on screen
' INCR!    0 Increment for leaf change at each step
' LADB!    0 Limit leaf position can be far to left direction
'          from most right leaf in side A
' LALIMIT! 0 Limit leaf position can be reached to left direction
'          in side A
' LAPLUS!  0 Most right leaf position in side A
' LBDIF!   0 Limit leaf position can be far to left direction
'          from most right leaf in side B
' LBLIMIT! 0 Limit leaf position can be reached to left direction
'          in side B
' LBPLUS!  0 Most right leaf position in side A
' LEAFID   0 Current leaf ID selected
' MAXMLCDD! 1 Max. of difference among leaves
' MINMLCFLD! 1 Max. of leaf stretch to opposite side
' OPPX!    0 Leaf position of opposite leaf
' ROW      1 Index for first row in menu box
' SIDES    0 Indicates current leaf side (A or B)
' SA!      0 Sine value of collimator angle
'
' FILES_USED:
' None
'
' SUBROUTINES_CALLED:
' MOVHCURABS HALO, move crosshair cursor to (X,Y)
'
' AUTHOR:
' Siyong Kim
'

```

```

' REVISION_HISTORY:
'
'
' {=====
'
' ===== GET LIMIT LEAF POSITION =====

J = LEAFNUM - 1

LAPLUS! = AXDATA!(0,0)
LBPLUS! = BXDATA!(0,0)

FOR I = 1 TO J
  IF AXDATA!(0,I) > LAPLUS! THEN
    IF I <> LEAFID - 1 THEN
      LAPLUS! = AXDATA!(0,I)
    END IF
  END IF
  IF BXDATA!(0,I) > LBPLUS! THEN
    IF I <> LEAFID - 1 THEN
      LBPLUS! = BXDATA!(0,I)
    END IF
  END IF
END IF
NEXT I

LADIF! = LAPLUS! - MAXMLCDF!
LBDIF! = LBPLUS! - MAXMLCDF!

'===== SIDE B =====
IF LBDIF! > -MAXMLCFLD! THEN
  LBLIMIT! = LBDIF!
ELSE
  LBLIMIT! = -MAXMLCFLD!
END IF

'===== SIDE A =====
OPPX! = BXDATA!(0, LEAFID-1)
IF OPPIX! > LADIF! THEN
  LALIMIT! = OPPIX!
ELSE
  LALIMIT! = LADIF!
END IF
IF LALIMIT! < -MINMLCFLD! THEN
  LALIMIT! = -MINMLCFLD!
END IF

'===== GET CHANGED LEAF POSITION =====

IF SIDES = "B" THEN
  CURX! = CURX! - INCR!
  IF CURX! <= LBLIMIT! THEN
    OS.Sound 262, 1
    CURX! = LBLIMIT!
  END IF
ELSE
  CURX! = CURX! - INCR!
  IF CURX! <= LALIMIT! THEN
    OS.Sound 262, 1
    CURX! = LALIMIT!
  END IF
END IF

CURXS! = CURX! * CA! - CURY! * SA!
CURYS! = CURY! * CA! + CURX! * SA!

CALLS MOVHCURABS(CURXS!, CURYS!)
LOCATE ROW, 3
PRINT USING "LEAF POSITION: <>## #>"; CURX!
END SUB
' {=====

```

```

SUBROUTINE:
  LEAFUP ()

SYNOPSIS:
  INCLUDE comir.inc
  INCLUDE comir7.inc

SUB LEAFUP STATIC
1500
DESCRIPTION:
  This subroutine select upper leaf during manual fit

ASSUMPTIONS:
  This subroutine assumes valid input variables

GLOBAL VARIABLES:
  AXDATA(I)  I X-coordinate data of leaf A
  AYDATA(I)  I Y-coordinate data of leaf A
  BXDATA(I)  I X-coordinate data of leaf B
  BYDATA(I)  I Y-coordinate data of leaf B
  CA!        O Cosine value of collimator angle
  CURX!      O Current X of selected leaf
  CURXS!     O Current X of selected leaf for display on screen
  CURY!      O Current Y of selected leaf
  CURYS!     O Current Y of selected leaf for display on screen
  LEAFID     O Current leaf ID selected
  LEAFNUM    O Number of leaves in one side (26 for Varian, 40 for Philips)
  ROW        I Index for first row in menu box
  SIDES      O Indicates current leaf side (A or B)
  SA!        O Sine value of collimator angle

FILES_USED:
  None

SUBROUTINES_CALLED:
  MOVHCURABS HALO, move crosshair cursor to (X,Y)
  NOTELEAF   Assign different color to selected leaf
              during leaf change in same side

AUTHOR:
  Siyong Kim

REVISION_HISTORY:

=====
!
IF LEAFID >= LEAFNUM THEN
  LEAFID = 1
ELSE
  LEAFID = LEAFID + 1
END IF
IF SIDES = "B" THEN
  CURY! = 0.5 * (BYDATA!(0,LEAFID-1) + BYDATA!(3,LEAFID-1))
  CURX! = BXDATA!(0,LEAFID-1)
ELSE
  CURY! = 0.5 * (AYDATA!(0,LEAFID-1) + AYDATA!(3,LEAFID-1))
  CURX! = AXDATA!(0,LEAFID-1)
END IF
CALL NOTELEAF

CURXS! = CURX! * CA! + CURY! * SA!
CURYS! = CURY! * CA! + CURX! * SA!

CALLS MOVHCURABS(CURXS!, CURYS!)
LOCATE ROW, 3
PRINT USING "LEAF POSITION: c+## #b "; CURX!
LOCATE ROW + 2, 42
PRINT "Use ", CHR$(24), " ", CHR$(25), " to select leaf ", "(" , LEAFID, " )"
```

```

END SUB
=====
SUBROUTINE
  LEAFRT ()
SYNOPSIS:
  INCLUDE comrinc
  INCLUDE comr7 inc
SUB LEAFRT STATIC
1600
DESCRIPTION:
  This subroutine move leaf to left direction during manual fit
ASSUMPTIONS:
  This subroutine assumes valid input variables.
GLOBAL_VARIABLES:
  AXDATA(I)  I X-coordinate data of leaf A
  BXDATA(I)  I X-coordinate data of leaf B
  CA!        O Cosine value of collimator angle
  CURX!      O Current X of selected leaf
  CURXS!     O Current X of selected leaf for display on screen
  CURY!      O Current Y of selected leaf
  CURYS!     O Current Y of selected leaf for display on screen
  INCR!      O Increment for leaf change at each stop
  LADIF!     O Limit leaf position can be far to right direction
              from most left leaf in side A
  LALIMIT!   O Limit leaf position can be reached to right direction
              in side A
  LAMINUS!   O Most left leaf position in side A
  LBDEF!     O Limit leaf position can be far to right direction
              from most left leaf in side B
  LBLIMIT!   O Limit leaf position can be reached to right direction
              in side B
  LBMINUS!   O Most left leaf position in side B
  LEAFID     O Current leaf ID selected
  MAXMLCFLD! I Max. of difference among leaves
  MINMLCFLD! I Max. of leaf stretch to opposite side
  OPPX!      O Leaf position of opposite leaf
  ROW        I Index for first row in menu box
  SIDES      O Indicates current leaf side (A or B)
  SA!        O Sine value of collimator angle
FILES_USED:
  None
SUBROUTINES_CALLED:
  MOVHCURABS  HALO, move crosshair cursor to (X,Y)
AUTHOR:
  Siyong Kim
REVISION_HISTORY:
=====
!
!===== GET LIMIT LEAF POSITION =====
J = LEAFNUM - 1
LAMINUS! = AXDATA(0,0)
LBMINUS! = BXDATA(0,0)
FOR I = 1 TO J
  IF AXDATA(0,I) < LAMINUS! THEN
    IF I <= LEAFID - 1 THEN
      LAMINUS! = AXDATA(0,I)

```

```

        END IF
    END IF
    IF BXDATA%(0,I) > LBMINUS! THEN
        IF I <= LEAFID - 1 THEN
            LBMINUS! = BXDATA%(0,I)
        END IF
    END IF
NEXT I

LADIF! = LAMINUS! + MAXMLCDIF!
LBDIF! = LBMINUS! + MAXMLCDIF!

'===== SIDE A =====
IF LADIF! < MAXMLCFLD! THEN
    LALIMIT! = LADIF!
ELSE
    LALIMIT! = MAXMLCFLD!
END IF

'===== SIDE B =====
OPPX! = AXDATA%(0, LEAFID-1)
IF OPPIX! < LBDIF! THEN
    LBLIMIT! = OPPIX!
ELSE
    LBLIMIT! = LBDIF!
END IF
IF LBLIMIT! > MINMLCFLD! THEN
    LBLIMIT! = MINMLCFLD!
END IF

'===== GET CHANGED LEAF POSITION =====
IF SIDES = "A" THEN
    CURX! = CURX! + INCR!
    IF CURX! >= LALIMIT! THEN
        OS Sound 262, 1
        CURX! = LALIMIT!
    END IF
ELSE
    CURX! = CURX! + INCR!
    IF CURX! >= LBLIMIT! THEN
        OS Sound 262, 1
        CURX! = LBLIMIT!
    END IF
END IF

CURXS! = CURX!*CA!*CURY!*SA!
CURYS! = CURY!*CA! + CURX!*SA!

CALLS MOVHCURABS(CURXS!, CURYS!)
LOCATE ROW, 3
PRINT USING "LEAF POSITION: <<## ##>>"; CURX!

```

END SUB

```

' {=====}
'
' SUBROUTINE:
' LEAFDN ()
'
' SYNOPSIS:
' INCLUDE comir.inc
' INCLUDE comir7.inc
'
SUB LEAFDN STATIC
1700
'
' DESCRIPTION:
' This subroutine select lower leaf during manual fit
'
' ASSUMPTIONS:
' This subroutine assumes valid input variables.

```

```

GLOBAL_VARIABLES:
  AXDATA(I)  I X-coordinate data of leaf A
  AYDATA(I)  I Y-coordinate data of leaf A
  BXDATA(I)  I X-coordinate data of leaf B
  BYDATA(I)  I Y-coordinate data of leaf B
  CA!        O Cosine value of collimator angle
  CURX!      O Current X of selected leaf
  CURXS!     O Current X of selected leaf for display on screen
  CURY!      O Current Y of selected leaf
  CURYS!     O Current Y of selected leaf for display on screen
  LEAFID     O Current leaf ID selected
  LEAFNUM    O Number of leaves in one side (26 for Varian, 40 for Pithips)
  ROW        I Index for first row in menu box
  SIDES      O Indicates current leaf side (A or B)
  SA!        O Sine value of collimator angle

```

```

FILES_USED:
  None

```

```

SUBROUTINES_CALLED:
  MOVHCURABS  HALO, move crosshair cursor to (X,Y)
  NOTELEAF    Assign different color to selected leaf
               during leaf change in same side

```

```

AUTHOR:
  Siyong Kim

```

```

REVISION_HISTORY:

```

```

=====
*
IF LEAFID <= 1 THEN
  LEAFID = LEAFNUM
ELSE
  LEAFID = LEAFID - 1
END IF
IF SIDES = "B" THEN
  CURY! = 0.5*(BYDATA!(0,LEAFID-1)+BYDATA!(3,LEAFID-1))
  CURX! = BXDATA!(0,LEAFID-1)
ELSE
  CURY! = 0.5*(AYDATA!(0,LEAFID-1)+AYDATA!(3,LEAFID-1))
  CURX! = AXDATA!(0,LEAFID-1)
END IF
CALL NOTELEAF

CURXS! = CURX! * CA! - CURY! * SA!
CURYS! = CURY! * CA! + CURX! * SA!

CALLS MOVHCURABS(CURXS!, CURYS!)
LOCATE ROW, 3
PRINT USING "LEAF POSITION: <+###.##>:", CURX!
LOCATE ROW + 2, 42
PRINT "Use "; CHR$(24); " ", CHR$(25); " to select leaf "; "("; LEAFID; "),"

```

```

END SUB
=====

```

```

SUBROUTINE
  REDRAWMLC()

```

```

SYNOPSIS:
  INCLUDE comir.inc
  INCLUDE comir7.inc

```

```

SUB REDRAWMLC STATIC
1800

```

```

DESCRIPTION:
  This subroutine redraws MLC leaf changed during manual fit

```

```

* ASSUMPTIONS:
*   This subroutine assumes valid input variables.

* GLOBAL_VARIABLES:
*   AXDATA%()  1X-coordinate data of leaf A
*   AXDATAS%() 1X-coordinate data of leaf A for display on screen
*   AYDATA%()  1Y-coordinate data of leaf A
*   AYDATAS%() 1Y-coordinate data of leaf A for display on screen
*   BAXIS%     1 Lower left Y world coordinate
*   BXDATA%()  1X-coordinate data of leaf B
*   BXDATAS%() 1X-coordinate data of leaf B for display on screen
*   BYDATA%()  1Y-coordinate data of leaf B
*   BYDATAS%() 1Y-coordinate data of leaf B for display on screen
*   CA%        0 Cosine value of collimator angle
*   CLROL%     1 Original color index for graphics
*   LAXIS%     1 Lower left X world coordinate
*   LEAFID%    0 Current leaf ID selected
*   MLCOPTMODE 1 Indicate type of fit (1=auto/2>manual)
*   NOTECOL%   1 Color index for selected leaf
*   SA%        0 Sine value of collimator angle
*   SIDES%     0 Indicates current leaf side (A or B)
*   XORMODE    1 Rubber band mode on/off

* FILES_USED:
*   None

* SUBROUTINES_CALLED:
*   DISDATA    Display isodose/phantom headings and data
*   DRWFLD     Draw field outline and MLC
*   INQCLR     HALO, inquire color index at (X,Y)
*   MPLDDATA   Get collimator opening and field outline for MLC field
*   MOVABS     HALO, move graphics cursor to (X,Y)
*   MOVHCURABS HALO, move crosshair cursor to (X,Y)
*   POLYLNABS  HALO, draw a polygon specified by absolute points
*   SETCOLOR   HALO, set active color
*   SETXOR     HALO, set hubberband mode

* AUTHOR:
*   Siyong Kim

* REVISION_HISTORY:
*
* =====
* !
* ===== REDRAW MLC LEAVES =====
* XORMODE=0
* CALLS SETXOR(XORMODE)

* IF SIDES="A" THEN
*   AXDATA%()=0, LEAFID-1)=CURX%
*   AXDATA%(1, LEAFID-1)=AXDATA%(0, LEAFID-1)+LEAFLEN%
*   AXDATA%(2, LEAFID-1)=AXDATA%(0, LEAFID-1)+LEAFLEN%
*   AXDATA%(3, LEAFID-1)=CURX%
*   AXDATA%(4, LEAFID-1)=CURX%
* ELSE
*   BXDATA%(0, LEAFID-1)=CURX%
*   BXDATA%(1, LEAFID-1)=BXDATA%(0, LEAFID-1)+LEAFLEN%
*   BXDATA%(2, LEAFID-1)=BXDATA%(0, LEAFID-1)+LEAFLEN%
*   BXDATA%(3, LEAFID-1)=CURX%
*   BXDATA%(4, LEAFID-1)=CURX%
* END IF
* MLCOPTMODE = 1
* CALL MPLDDATA
* CALL DRWFLD
* CALL DISDATA

* J=LEAFID-1
* CALLS SETCOLOR(NOTECOL%)
* IF SIDES="A" THEN
*   CALLS MOVABS(AXDATAS%(0,J), AYDATAS%(0,J))

```

```

      CALLS POLYLNABS(AXDATAS(I(0,J), AYDATAS(I(0,J),5)
ELSE
      CALLS MOVABS(BXDATAS(I(0,J), BYDATAS(I(0,J))
      CALLS POLYLNABS(BXDATAS(I(0,J), BYDATAS(I(0,J),5)
END IF
XORMODE=1
CALLS SETXOR(XORMODE)
CURXS=CURX!*CA1-CURY!*SA1
CURYS=CURY!*CA1+CURX!*SA1
CALLS MOVHCURABS(CURXS1, CURYS1)
CALLS INQCLR(LAXIS1, BAXIS1, CLROLD)
CALLS SETCOLOR(CLROLD)

END SUB
' =====
'
' SUBROUTINE:
'   NOTELEAF ()
'
' SYNOPSIS:
'   INCLUDE constr.inc
'   INCLUDE constr7.inc
'
SUB NOTELEAF STATIC
1900
'
' DESCRIPTION:
'   This subroutine assign different color to selected leaf
'   during leaf change in same side
'
' ASSUMPTIONS:
'   This subroutine assumes valid input variables.
'
' GLOBAL_VARIABLES:
'   AXDATAS(I)    I X-coordinate data of leaf A for display on screen
'   AYDATAS(I)    I Y-coordinate data of leaf A for display on screen
'   BXDATAS(I)    I X-coordinate data of leaf B for display on screen
'   BYDATAS(I)    I Y-coordinate data of leaf B for display on screen
'   LEAFCOLR      I Color index for MLC leaf
'   LEAFDNID      O Lower leaf ID from current leaf selected
'   LEAFID        O Current leaf ID selected
'   LEAFNUM       O Number of leaves in one side (26 for Varian, 40 for Philips)
'   LEAFUID       O Upper leaf ID from current leaf selected
'   NOTBCOLR      I Color index for selected leaf
'   SIDES         O Indicates current leaf side (A or B)
'   XORMODE       I Rubber band mode on/off
'
' FILES_USED:
'   None
'
' SUBROUTINES_CALLED:
'   DELHCUR      HALO, delete crosshair cursor
'   MOVABS       HALO, move graphics cursor to (X,Y)
'   POLYLNABS    HALO, draw a polygon specified by absolute points
'   SETCOLOR     HALO, set active color
'   SETXOR       HALO, set bubbleband mode
'
' AUTHOR:
'   Siyeon Kim
'
' REVISION_HISTORY:
'
'
' =====
'
' ===== NOTIFY SELECTED LEAF =====
CALLS DELHCUR
XORMODE=0
CALLS SETXOR(XORMODE)

IF LEAFID = 1 THEN

```

```

        LEAFUPID= 2
        LEAFDID = LEAFNUM
    ELSEIF LEAFID = LEAFNUM THEN
        LEAFUPID = 1
        LEAFDID = LEAFNUM - 1
    ELSE
        LEAFUPID = LEAFID + 1
        LEAFDID = LEAFID - 1
    ENO IF

    J=LEAFID-1
    JUP=LEAFUPID-1
    JDN=LEAFDID-1

    IF SIDES="A" THEN
        CALLS SETCOLOR(LEAFCOLR)
        CALLS MOVABS(AXDATAS(0,JUP), AYDATAS(0,JUP))
        CALLS POLYLNABS(AXDATAS(0,JUP), AYDATAS(0,JUP),5)
        CALLS MOVABS(AXDATAS(0,JDN), AYDATAS(0,JDN))
        CALLS POLYLNABS(AXDATAS(0,JDN), AYDATAS(0,JDN),5)

        CALLS SETCOLOR(NOTECOLR)
        CALLS MOVABS(AXDATAS(0,J), AYDATAS(0,J))
        CALLS POLYLNABS(AXDATAS(0,J), AYDATAS(0,J),5)
        CALLS SETCOLOR(LEAFCOLR)
    ELSE
        CALLS SETCOLOR(LEAFCOLR)
        CALLS MOVABS(BXDATAS(0,JUP), BYDATAS(0,JUP))
        CALLS POLYLNABS(BXDATAS(0,JUP), BYDATAS(0,JUP),5)
        CALLS MOVABS(BXDATAS(0,JDN), BYDATAS(0,JDN))
        CALLS POLYLNABS(BXDATAS(0,JDN), BYDATAS(0,JDN),5)

        CALLS SETCOLOR(NOTECOLR)
        CALLS MOVABS(BXDATAS(0,J), BYDATAS(0,J))
        CALLS POLYLNABS(BXDATAS(0,J), BYDATAS(0,J),5)
        CALLS SETCOLOR(LEAFCOLR)
    END IF

    XORMODE=1
    CALLS SETXOR(XORMODE)

END SUB
' [=====]
'
' SUBROUTINE:
'   NOTE2LEAF ()
'
' SYNOPSIS:
'   INCLUDE com1c.inc
'   INCLUDE com17.inc
'
SUB NOTE2LEAF STATIC
2000
'
' DESCRIPTION:
'   This subroutine move cursor and assign different color to selected
'   leaf during leaf change between two different sides
'
' ASSUMPTIONS:
'   This subroutine assumes valid input variables.
'
' GLOBAL VARIABLES:
'   AXDATA()      I X-coordinate data of leaf A
'   AXDATAS()     I X-coordinate data of leaf A for display on screen
'   AYDATAS()     I Y-coordinate data of leaf A for display on screen
'   BXDATA()      I X-coordinate data of leaf B
'   BXDATAS()     I X-coordinate data of leaf B for display on screen
'   BYDATAS()     I Y-coordinate data of leaf B for display on screen
'   CA!           O Cosine value of collimator angle
'   CURX!         O Current X of selected leaf
'   CURXS!        O Current X of selected leaf for display on screen

```

```

CURY!      O Current Y of selected leaf
CURYS!     O Current Y of selected leaf for display on screen
LEAPCOLR   I Color index for MLC leaf
LEAPID     O Current leaf ID selected
NOTECOLR   I Color index for selected leaf
ROW        I Index for first row in menu box
SA!        O Sine value of collimator angle
SIDES      O Indicates current leaf side (A or B)
XORMODE    I Rubber band mode on/off

FILES_USED:
None

SUBROUTINES_CALLED:
DELHCUR    HALO, delete crosshair cursor
MOVABS     HALO, move graphics cursor to (X,Y)
MOVHCURABS HALO, move crosshair cursor to (X,Y)
POLYLNABS  HALO, draw a polygon specified by absolute points
SETCOLOR   HALO, set active color
SETXOR     HALO, set rubberband mode

AUTHOR:
Siyong Kim

REVISION_HISTORY:

```

```

*=====
*!
*===== NOTIFY SELECTED LEAF =====
CALLS DELHCUR
XORMODE=0
CALLS SETXOR(XORMODE)

J=LEAPID-1
IF SIDES="A" THEN
  CALLS MOVABS(AXDATAS(0,J), AYDATAS(0,J))
  CALLS SETCOLOR(NOTECOLR)
  CALLS POLYLNABS(AXDATAS(0,J), AYDATAS(0,J),5)
  CALLS SETCOLOR(LEAPCOLR)
  CALLS MOVABS(BXDATAS(0,J), BYDATAS(0,J))
  CALLS POLYLNABS(BXDATAS(0,J), BYDATAS(0,J),5)
ELSE
  CALLS MOVABS(BXDATAS(0,J), BYDATAS(0,J))
  CALLS SETCOLOR(NOTECOLR)
  CALLS POLYLNABS(BXDATAS(0,J), BYDATAS(0,J),5)
  CALLS SETCOLOR(LEAPCOLR)
  CALLS MOVABS(AXDATAS(0,J), AYDATAS(0,J))
  CALLS POLYLNABS(AXDATAS(0,J), AYDATAS(0,J),5)
END IF

XORMODE=1
CALLS SETXOR(XORMODE)
IF SIDES="A" THEN
  CURX=AXDATA(0,J)
  CURXS=CURX**CA1-CURY**SA1
  CURYS=CURY**CA1+CURX**SA1
  CALLS MOVHCURABS(CURXS,CURYS)
ELSE
  CURX=BXDATA(0,J)
  CURXS=CURX**CA1-CURY**SA1
  CURYS=CURY**CA1+CURX**SA1
  CALLS MOVHCURABS(CURXS,CURYS)
END IF
LOCATE ROW, 3
PRINT USING "LEAF POSITION <+## #>": CURX'
END SUB
*=====
*
* SUBROUTINE
* MLCSETMENU ()

```

```

* SYNOPSIS:
*   INCLUDE comocrs.inc
*   INCLUDE comir.inc
SUB MLCSETMENU STATIC
2300
* DESCRIPTION:
*   This subroutine displays MLC field editor menu
* ASSUMPTIONS:
*   This subroutine assumes valid input variables.
* GLOBAL VARIABLES:
*   CALPTNUM      1 Number of calculation points
*   CHCS()        0 An array of character strings which make up main menu
*   OPFLFLAG      1 Are depths defined (0=no, 1=yes)
*   MLCSETFLAG    1 MLC is set? (0=no, 1=yes)
*   WDGANG        0 Wedge angle (degrees)
* FILES USED:
*   None
* SUBROUTINES CALLED:
*   BLDMENU       Display menu function keys & active keys (arrows,+,*,
*                   PgUp,PgDn)
* AUTHOR:
*   Syong Kim
* REVISION HISTORY:
*
* =====
*   ERASE CHCS
*   CHCS(0) = " MLC FIELD EDITOR "
*   CHCS(1) = "Autofit"
*   CHCS(2) = "Autofit-Under"
*   CHCS(3) = "Autofit-Over"
*   CHCS(5) = "Manual Fit"
*   IF WDGANG = 0 THEN
*     CHCS(6) = "Coll. Angle"
*   END IF
*   CHCS(9) = "Offset X"
*   CHCS(10) = "Offset Y"
*   IF MLCSETFLAG = 1 THEN
*     CHCS(7) = "Calc Points"
*   END IF
*   IF CALPTNUM > 0 THEN
*     CHCS(11) = "Point Depths"
*   END IF
*   IF OPFLFLAG = 1 THEN
*     CHCS(17) = "ON"
*   END IF
*   CALL BLDMENU
END SUB
*
* =====
* SUBROUTINE
*   AUTOFIT ()
*
* SYNOPSIS:
*   INCLUDE comocrs.inc
*   INCLUDE comir.inc
*
SUB AUTOFIT STATIC
2600
* DESCRIPTION:
*   This subroutine carry out geometric optimization for MLC field

```

```

      automatically
*
* ASSUMPTIONS:
*   This subroutine assumes valid input variables
*
* GLOBAL_VARIABLES:
*   CONTSHIFTX!  1 MLC offset in X-dir. (cm)
*   MLCFLAG      1 MLC field editor is on (0=no, 1=yes)
*   MLCOPTMODE    1 Indicate type of fit (1=auto/2>manual)
*   OLDSHIFTX!   1 MLC offset in X-dir. (cm)
*
* FILES_USED:
*   None
*
* SUBROUTINES_CALLED:
*   DISDATA      Display isodose/phantom headings and data
*   DRWFELD      Draw field outline and MLC
*   MFLDDATA      Get collimator opening and field outline for MLC field
*   MLCINI        Set MLC dimension and initial leaf position
*   MLCOPT        Search geometrically optimized MLC leaf position
*
* AUTHOR:
*   Siyoung Kim
*
* REVISION_HISTORY:

```

```

* [=====]
*
*   OLDSHIFTX:=CONTSHIFTX!
*   IF MLCFLAG = 1 THEN
*     CALL MLCINI
*     CALL MLCOPT
*     MLCOPTMODE = 1
*     CALL MFLDDATA
*     CALL DRWFELD
*     CALL DISDATA
*   ELSE
*     OS Sound 261, 2
*   END IF
*   CONTSHIFTX!:=OLDSHIFTX!
* END SUB

```

```

* [=====]
*
* SUBROUTINE:
*   MANUFIT ()
*
* SYNOPSIS:
*   INCLUDE comproc.inc
*   INCLUDE comvar.inc

```

```

SUB MANUFIT STATIC
2700

```

```

* DESCRIPTION:
*   This subroutine carry out geometric optimization for MLC field
*   manually
*
* ASSUMPTIONS:
*   This subroutine assumes valid input variables.
*
* GLOBAL_VARIABLES:
*   CONTSHIFTX!  1 MLC offset in X-dir. (cm)
*   MLCFLAG      1 MLC field editor is on (0=no, 1=yes)
*   MLCOPTMODE    1 Indicate type of fit (1=auto/2>manual)
*   OLDSHIFTX!   1 MLC offset in X-dir. (cm)
*   MLCSTART      1 Indicate specific type of MLC edit
*                 (1=autofit, 2=auto-under, 3=auto-over, 4>manual)

```

```

* FILES_USED:
*   None

```

```

SUBROUTINES_CALLED:
  DISDATA      Display isodose/phantom headings and data
  DRWFELD      Draw field outline and MLC
  MANOPTI      Enables manual MLC field editing
  MPLDDATA     Get collimator opening and field outline for MLC field
  MLCINI       Set MLC dimension and initial leaf position
  MLCOPT       Search geometrically optimized MLC leaf position

AUTHOR:
  Siyong Kim

REVISION_HISTORY:

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```

      OLDSHIFTX:=CONTSHIFTX!
      IF MLCFLAG = 1 THEN
        IF MLCSTART = 0 THEN
          CALL MLCINI
          CALL MLCOPT
          MLCOPTIMODE = 1
          CALL MPLDDATA
          CALL DRWFELD
          CALL DISDATA
        END IF
        CALL MANOPTI
      ELSE
        OS.Sound 261, 2
      END IF
      CONTSHIFTX:=OLDSHIFTX!
END SUB

```

```

SUBROUTINE:
  MLCOPTUNDER ()

SYNOPSIS:
  INCLUDE comir.inc
  INCLUDE com7.inc

SUB MLCOPTUNDER STATIC
2800

DESCRIPTION:
  This subroutine search geometrically underblocked MLC leaf position

ASSUMPTIONS:
  This subroutine assumes valid input variables

GLOBAL_VARIABLES:
  AXDATA()    I X-coordinate data of leaf A
  AYDATA()    I Y-coordinate data of leaf A
  BXDATA()    I X-coordinate data of leaf B
  CA!         O Cosine value of collimator angle
  CCWX()      O Temporary X-coord. for field outline rotated
               opposite to collimator rotation
  CCWY()      O Temporary Y-coord. for field outline rotated
               opposite to collimator rotation
  CONTSHIFTX! I MLC offset in X-dir. (cm)
  CONTSHIFTY! I MLC offset in Y-dir. (cm)
  DIFF!       O Difference between longest leaf and each one
  DY!         O Difference in Y between two consecutive vertices (cm)
  FLDEEDGE()  I Irregular field outline coordinates (cm*100)
  FLDMAXVER!  O Highest point of outline in vertical direction
  FLDMINVER!  O Lowest point of outline in vertical direction
  FLDPITNUM   I Number of vertices in field outline
  GRA!        O Gradient between two vertices
  LA()        O Temporary leaf position in side A
  LABIFF!     O Difference between most right and most left leaves in side A
  LAMINUS!    O Most left leaf position in side A

```

```

* LAPLUS!      O Most right leaf position in side A
* LB(I)        O Temporary leaf position in side B
* LBDIFF!      O Difference between most right and most left leaves in side B
* LBMINUS!     O Most left leaf position in side A
* LBPLUS!      O Most right leaf position in side A
* LEAFLEN!     O Length of MLC leaf
* LEAFNUM!     O Number of leaves in one side (26 for Varian, 40 for Philips)
* LEAFWID!     O Width of MLC leaf
* MAXMLCDBP!   I Max. of difference among leaves
* MAXMLCFLD!   I Max. of MLC field size in one side
* MINMLCFLD!   I Max. of leaf stretch to opposite side
* MLAXIS!      I Initial A leaf position before optimization process
* MAXMLCDBP!   I Max. of difference among leaves
* MRAXIS!      I Initial B leaf position before optimization process
* OPTERRFLAG!  O Indicate type of error during optimization
* SA!          O Size value of collimator angle
* XMAG(I)      O X-coord. for field outline with offset (cm)
* XORG!        O Original X-coord. for field outline (cm)
* XPARA!       O Optimized leaf position during optimization process
* YBOT!        O Y-coord. at bottom point for each leaf (cm)
* YMAG(I)      O Y-coord. for field outline with offset (cm)
* YORG!        O Original Y-coord. for field outline (cm)
* YTOP!        O Y-coord. at top point for each leaf (cm)

FILES_USED:
None

SUBROUTINES_CALLED:
  CONVERTANG  Convert collimator angle in degree to radian
               and get sine, cosine values

AUTHOR:
  Siyong Kim

REVISION_HISTORY:

*
* =====
*
  DIM LA(0 TO LEAFNUM-1), LB(0 TO LEAFNUM-1), CCWX(0 TO FLDPTNUM+1), CCWY(0 TO FLDPTNUM+1)
  *===== TOP AND BOTTOM POSITION OF EACH LEAF =====

  CALL CONVERTANG

  FOR I=0 TO FLDPTNUM
    XORG(I)=FLDEDGE(I,0)*0.01  *XORG!: ORIGINAL CONTOUR DATA
    YORG(I)=FLDEDGE(I,1)*0.01
    XMAG(I)=XORG(I)+CONTSHIFTX! *XMAG!: PROJECTED AND SHIFTED
    YMAG(I)=YORG(I)+CONTSHIFTY! *YMAG!: SHIFTED
    CCWX(I)=XMAG(I)*CA! + YMAG(I)*SA! *CCWX!: ROTATED IN CCW DIRECTION
    CCWY(I)=YMAG(I)*CA! - XMAG(I)*SA!
  NEXT I
  *===== ENSURE CLOSED CURVE =====
  CCWX(FLDPTNUM+1)=CCWX(0)
  CCWY(FLDPTNUM+1)=CCWY(0)
  *===== INITIAL LEAF POSITION =====
  MLAXIS! = -40!
  MRAXIS! = 40!

  J=LEAFNUM-1
  FOR I=0 TO J
    LA(I)=MLAXIS!
    LB(I)=MRAXIS!
  NEXT I
  FOR I=0 TO FLDPTNUM
    DY!=CCWY(I+1)-CCWY(I)
    IF DY! > 0.0 THEN
      *===== COMPARE WITH TOP POSITION =====
      FOR J=0 TO LEAFNUM-1
        YTOP! = AYDATA(J)
        IF YTOP! >= CCWY(I) AND YTOP! <= CCWY(I+1) THEN

```

```

      GRA=(CCWX(I)+1)-CCWX(I))(CCWY(I+1)-CCWY(I))
      XPARA=GRA*(YTOP-CCWY(I))+CCWX(I)
      IF XPARA > LA(I) THEN
        LA(I)=XPARA
      END IF
      IF XPARA < LB(I) THEN
        LB(I)=XPARA
      END IF
    END IF
  NEXT J
  ===== COMPARE WITH BOTTOM POSITION =====
  FOR J=0 TO LEAFNUM-1
    YBOT= AYDATA(0,J)
    IF YBOT >= CCWY(I) AND YBOT <= CCWY(I+1) THEN
      GRA=(CCWX(I+1)-CCWX(I))(CCWY(I+1)-CCWY(I))
      XPARA=GRA*(YBOT-CCWY(I))+CCWX(I)
      IF XPARA > LA(I) THEN
        LA(I)=XPARA
      END IF
      IF XPARA < LB(I) THEN
        LB(I)=XPARA
      END IF
    END IF
  NEXT J
END IF

IF DY! < 0.0 THEN
  ===== COMPARE WITH TOP POSITION =====
  FOR J=0 TO LEAFNUM-1
    YTOP= AYDATA(3,J)
    IF YTOP <= CCWY(I) AND YTOP >= CCWY(I+1) THEN
      GRA=(CCWX(I+1)-CCWX(I))(CCWY(I+1)-CCWY(I))
      XPARA=GRA*(YTOP-CCWY(I))+CCWX(I)
      IF XPARA > LA(I) THEN
        LA(I)=XPARA
      END IF
      IF XPARA < LB(I) THEN
        LB(I)=XPARA
      END IF
    END IF
  NEXT J
  ===== COMPARE WITH BOTTOM POSITION =====
  FOR J=0 TO LEAFNUM-1
    YBOT= AYDATA(0,J)
    IF YBOT <= CCWY(I) AND YBOT >= CCWY(I+1) THEN
      GRA=(CCWX(I+1)-CCWX(I))(CCWY(I+1)-CCWY(I))
      XPARA=GRA*(YBOT-CCWY(I))+CCWX(I)
      IF XPARA > LA(I) THEN
        LA(I)=XPARA
      END IF
      IF XPARA < LB(I) THEN
        LB(I)=XPARA
      END IF
    END IF
  NEXT J
END IF

IF DY! = 0.0 THEN
  ===== COMPARE WITH TOP POSITION =====
  FOR J=0 TO LEAFNUM-1
    YTOP= AYDATA(3,J)
    IF YTOP = CCWY(I) THEN
      XPARA=CCWY(I)
      IF XPARA > LA(I) THEN
        LA(I)=XPARA
      END IF
      IF XPARA < LB(I) THEN
        LB(I)=XPARA
      END IF
    END IF
  NEXT J
END IF

```

```

===== COMPARE WITH BOTTOM POSITION =====
FOR J=0 TO LEAFNUM-1
  YBOT1 = AYDATA(0,J)
  IF YBOT1 = CCWY(I) THEN
    XPARA1=CCWY(I)
    IF XPARA1 > LA(I) THEN
      LA(I)=XPARA1
    END IF
    IF XPARA1 < LB(I) THEN
      LB(I)=XPARA1
    END IF
  END IF
NEXT J
END IF
NEXT I

===== ADJUST THE ZEROS =====
J=LEAFNUM-1
FOR I=0 TO J
  IF LA(I)=MLAXIS1 THEN
    LA(I)=0.0
  END IF
  IF LB(I)=MRAXIS1 THEN
    LB(I)=0.0
  END IF
NEXT I

===== RESTRICTION CHECK =====
===== HORIZONTAL FIELD SIZE =====
J=LEAFNUM-1
FOR I=0 TO J
  IF LA(I) > MAXMLCFLD1 THEN
    LA(I)=MAXMLCFLD1
    OPTIERRFLAG = -77
  END IF
  IF LA(I) < -MINMLCFLD1 THEN
    LA(I)=-MINMLCFLD1
    OPTIERRFLAG = -77
  END IF
  IF LB(I) > MINMLCFLD1 THEN
    LB(I)=MINMLCFLD1
    OPTIERRFLAG = -77
  END IF
  IF LB(I) < -MAXMLCFLD1 THEN
    LB(I)=-MAXMLCFLD1
    OPTIERRFLAG = -77
  END IF
NEXT I

===== VERTICAL FIELD SIZE =====
MLCMAXVER1 = HLEAFNUM**LEAFWID1
FLDMAXVER1 = CCWY(0)
FLDMINVER1 = CCWY(I(0))
FOR I = 0 TO FLDPNTNUM
  IF CCWY(I) > FLDMAXVER1 THEN
    FLDMAXVER1 = CCWY(I)
  END IF
  IF CCWY(I) < FLDMINVER1 THEN
    FLDMINVER1 = CCWY(I)
  END IF
NEXT I
IF FLDMAXVER1 > MLCMAXVER1 OR FLDMINVER1 < -MLCMAXVER1 THEN
  IF OPTIERRFLAG = -77 THEN
    OPTIERRFLAG = -99
  ELSE
    OPTIERRFLAG = -88
  END IF
END IF
IF FLDMINVER1 > MLCMAXVER1 OR FLDMAXVER1 < -MLCMAXVER1 THEN
  OPTIERRFLAG = -100
END IF

===== CHECK MAX DIFFERENCE AMONG LEAVES =====

```

```

J = LEAFNUM - 1

LAPLUS! = LA!(0)
LAMINUS! = LA!(0)
LBPLUS! = LB!(0)
LBMINUS! = LB!(0)

FOR I = 1 TO J
  IF LA!(I) > LAPLUS! THEN
    LAPLUS! = LA!(I)
  END IF
  IF LA!(I) < LAMINUS! THEN
    LAMINUS! = LA!(I)
  END IF
  IF LB!(I) > LBPLUS! THEN
    LBPLUS! = LB!(I)
  END IF
  IF LB!(I) < LBMINUS! THEN
    LBMINUS! = LB!(I)
  END IF
NEXT I

LADIFF! = LAPLUS! - LAMINUS!
LBDIFF! = LBPLUS! - LBMINUS!

IF LADIFF! >= MAXMLCDIF! OR LBDIFF! >= MAXMLCDIF! THEN
  IF OPTERRFLAG = -77 THEN
    OPTERRFLAG = -377
  ELSEIF OPTERRFLAG = -48 THEN
    OPTERRFLAG = -368
  ELSEIF OPTERRFLAG = -99 THEN
    OPTERRFLAG = -399
  ELSEIF OPTERRFLAG = -100 THEN

  ELSE
    OPTERRFLAG = -33
  END IF
END IF

IF LADIFF! > MAXMLCDIF! THEN
  FOR I = 0 TO J
    DIFF! = LAPLUS! - LA!(I)
    IF DIFF! > MAXMLCDIF! THEN
      LA!(I) = LAPLUS! - MAXMLCDIF!
    END IF
  NEXT I
END IF

IF LBDIFF! > MAXMLCDIF! THEN
  FOR I = 0 TO J
    DIFF! = LB!(I) - LBMINUS!
    IF DIFF! > MAXMLCDIF! THEN
      LB!(I) = LBMINUS! + MAXMLCDIF!
    END IF
  NEXT I
END IF

'===== ASSIGN THE OPTIMIZED POSITION TO LEAF DATA =====
FOR I=0 TO LEAFNUM-1
  AXDATA%(0,I)=LA!(I)
  AXDATA%(1,I)=LA!(I)+LEAFLEN*
  AXDATA%(2,I)=LA!(I)+LEAFLEN*
  AXDATA%(3,I)=LA!(I)
  AXDATA%(4,I)=LA!(I)

  BXDATA%(0,I)=LB!(I)
  BXDATA%(1,I)=LB!(I)-LEAFLEN*
  BXDATA%(2,I)=LB!(I)-LEAFLEN*
  BXDATA%(3,I)=LB!(I)
  BXDATA%(4,I)=LB!(I)
NEXT I

```

ERASE LA1, LB1, CCWX1, CCWY1

END SUB

SUBROUTINE:
MLCOPTOVER ()

SYNOPSIS:
INCLUDE comar.inc
INCLUDE comar7.inc

SUB MLCOPTOVER STATIC
2900

DESCRIPTION:
This subroutine search geometrically overlapped MLC leaf position

ASSUMPTIONS:
This subroutine assumes valid input variables.

GLOBAL VARIABLES:

AXDATA(I) I X-coordinate data of leaf A
AYDATA(I) I Y-coordinate data of leaf A
BXDATA(I) I X-coordinate data of leaf B
CA! O Cosine value of collimator angle
CCWX(I) O Temporary X-coord. for field outline rotated
opposite to collimator rotation
CCWY(I) O Temporary Y-coord. for field outline rotated
opposite to collimator rotation
CONTSHTFTX! I MLC offset in X-dir. (cm)
CONTSHTFTY! I MLC offset in Y-dir. (cm)
DIFF! O Difference between longest leaf and each one
DY! O Difference in Y between two consecutive vertices (cm)
FLDEDGE(I) I Irregular field outline coordinates (cm*100)
FLDMAXVER! O Highest point of outline in vertical direction
FLDMINVER! O Lowest point of outline in vertical direction
FLDPTNUM I Number of vertices in field outline
GRA! O Gradient between two vertices
LA(I) O Temporary leaf position in side A
LA2(I) O Temporary leaf position in side A
LADIFF! O Difference between most right and most left leaves in side A
LAMINUS! O Most left leaf position in side A
LAPLUS! O Most right leaf position in side A
LB(I) O Temporary leaf position in side B
LB2(I) O Temporary leaf position in side B
LBDIFF! O Difference between most right and most left leaves in side B
LBMINUS! O Most left leaf position in side A
LBPLUS! O Most right leaf position in side A
LEAFLEN! O Length of MLC leaf
LEAFNUM O Number of leaves in one side (26 for Varian, 40 for Philips)
LEAFWID! O Width of MLC leaf
MAXMLCDF! I Max. of difference among leaves
MAXMLCFD! I Max. of MLC field size in one side
MINMLCFD! I Max. of leaf stretch to opposite side
MLAXIS! I Initial A leaf position before optimization process
MAXMLCDF! I Max. of difference among leaves
MRAXIS! I Initial B leaf position before optimization process
OPTERRFLAG O Indicate type of error during optimization
SA! O Sine value of collimator angle
XMAG(I) O X-coord. for field outline with offset (cm)
XORG! O Original X-coord. for field outline (cm)
XPARA! O Optimized leaf position during optimization process
YBOT! O Y-coord. at 1/3 bottom point for each leaf (cm)
YMAG(I) O Y-coord. for field outline with offset (cm)
YORG! O Original Y-coord. for field outline (cm)
YTOP! O Y-coord. at 2/3 top point for each leaf (cm)

FILES_USED:
None

```

SUBROUTINES_CALLED:
  CONVERTANG   Convert collimator angle in degree to radian
               and get sine, cosine values

AUTHOR:
  Siyong Kim

REVISION_HISTORY:
' =====
'
  DIM LA(0 TO LEAFNUM-1), LB(0 TO LEAFNUM-1), CCWX(0 TO FLDPTNUM+1), CCWY(0 TO FLDPTNUM+1)
  DIM LA2(0 TO LEAFNUM-1), LB2(0 TO LEAFNUM-1)
  '===== TURN THE CONTOUR TO ALIGN WITH COLLIMATOR ANGLE =====
  CALL CONVERTANG

  FOR I=0 TO FLDPTNUM
    XORG(1)=FLEDDGE(L,0)*0.01  'XORG(1): ORIGINAL CONTOUR DATA
    YORG(1)=FLEDDGE(L,1)*0.01
    XMAG(1)=XORG(1)+CONTSHIFTX!  'YMAG(1): SHIFTED
    YMAG(1)=YORG(1)+CONTSHIFTY!  'YMAG(1): SHIFTED
    CCWX(1)=XMAG(1)*CA! + YMAG(1)*SA!  'CCWX(1): ROTATED IN CCW DIRECTION
    CCWY(1)=YMAG(1)*CA! - XMAG(1)*SA!
  NEXT I
  '===== ENSURE CLOSED CURVE =====
  CCWX(FLDPTNUM+1)=CCWX(0)
  CCWY(FLDPTNUM+1)=CCWY(0)
  '===== INITIAL LEAF POSITION =====
  MLAXIS! = -40!
  MRAXIS! = 40!

  J=LEAFNUM-1
  FOR I=0 TO J
    LA(1)=MLAXIS!
    LB(1)=MRAXIS!
    LA2(1)=MLAXIS!
    LB2(1)=MRAXIS!
  NEXT I
  '===== COMPARE WITH TOP 1/3 POSITION =====
  FOR I=0 TO FLDPTNUM
    DY(1)=CCWY(1)-CCWY(0)
    IF DY(1) > 0.0 THEN
      FOR J=0 TO LEAFNUM-1
        YTOP(1) = AYDATA(0,J) + 2!*LEAFWID(1)/3!
        IF YTOP(1) >= CCWY(1) AND YTOP(1) <= CCWY(1+1) THEN
          GRA(1)=(CCWX(1+1)-CCWX(0))/(CCWY(1+1)-CCWY(0))
          XPARA(1)=GRA(1)*(YTOP(1)-CCWY(0))+CCWX(0)
          IF XPARA(1) > LA(1) THEN
            LA(1)=XPARA(1)
          END IF
          IF XPARA(1) < LB(1) THEN
            LB(1)=XPARA(1)
          END IF
        END IF
      NEXT J
    END IF
    IF DY(1) < 0.0 THEN
      FOR J=0 TO LEAFNUM-1
        YTOP(1) = AYDATA(0,J) + 2!*LEAFWID(1)/3!
        IF YTOP(1) <= CCWY(1) AND YTOP(1) >= CCWY(1+1) THEN
          GRA(1)=(CCWX(1+1)-CCWX(0))/(CCWY(1+1)-CCWY(0))
          XPARA(1)=GRA(1)*(YTOP(1)-CCWY(0))+CCWX(0)
          IF XPARA(1) > LA(1) THEN
            LA(1)=XPARA(1)
          END IF
          IF XPARA(1) < LB(1) THEN
            LB(1)=XPARA(1)
          END IF
        END IF
      NEXT J
    END IF
  NEXT I

```

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END IF

IF OY1 = 0.0 THEN
  FOR J=0 TO LEAFNUM-1
    YTOP1 = AYDATA(0,J) + 2*LEAFWID/3!
    IF YTOP1 = CCWY(1) THEN
      XPARA1 = CCWY(1)
      IF XPARA1 > LA1(0) THEN
        LA1(0) = XPARA1
      END IF
      IF XPARA1 < LB1(0) THEN
        LB1(0) = XPARA1
      END IF
    END IF
  NEXT J
END IF

NEXT I
===== COMPAR WITH BOTTOM 1/3 POSITION =====
FOR I=0 TO FLDPTNUM
  OY1 = CCWY(1+1) - CCWY(1)
  IF DY1 > 0.0 THEN
    FOR J=0 TO LEAFNUM-1
      YBOT1 = AYDATA(0,J) + LEAFWID/3!
      IF YBOT1 >= CCWY(1) AND YBOT1 <= CCWY(1+1) THEN
        GRA1 = (CCWX(1+1) - CCWX(1)) / (CCWY(1+1) - CCWY(1))
        XPARA1 = GRA1 * (YBOT1 - CCWY(1)) + CCWX(1)
        IF XPARA1 > LA2(0) THEN
          LA2(0) = XPARA1
        END IF
        IF XPARA1 < LB2(0) THEN
          LB2(0) = XPARA1
        END IF
      END IF
    NEXT J
  END IF

  IF DY1 < 0.0 THEN
    FOR J=0 TO LEAFNUM-1
      YBOT1 = AYDATA(0,J) + LEAFWID/3!
      IF YBOT1 <= CCWY(1) AND YBOT1 >= CCWY(1+1) THEN
        GRA1 = (CCWX(1+1) - CCWX(1)) / (CCWY(1+1) - CCWY(1))
        XPARA1 = GRA1 * (YBOT1 - CCWY(1)) + CCWX(1)
        IF XPARA1 > LA2(0) THEN
          LA2(0) = XPARA1
        END IF
        IF XPARA1 < LB2(0) THEN
          LB2(0) = XPARA1
        END IF
      END IF
    NEXT J
  END IF

  IF DY1 = 0.0 THEN
    FOR J=0 TO LEAFNUM-1
      YBOT1 = AYDATA(0,J) + LEAFWID/3!
      IF YBOT1 = CCWY(1) THEN
        XPARA1 = CCWY(1)
        IF XPARA1 > LA2(0) THEN
          LA2(0) = XPARA1
        END IF
        IF XPARA1 < LB2(0) THEN
          LB2(0) = XPARA1
        END IF
      END IF
    NEXT J
  END IF
END IF

NEXT I
===== FIND LEAF POSITION LA1 AND LB1 =====
I = LEAFNUM-1
FOR I=0 TO J

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      IF LA%(I) > LA2%(I) THEN
        LA%(I)=LA2%(I)
      END IF
      IF LB%(I) < LB2%(I) THEN
        LB%(I)=LB2%(I)
      END IF
    NEXT I

    !===== ADJUST THE ZEROS =====
    J=LEAFNUM-1
    FOR I=0 TO J
      IF LA%(I)=MLAXIS! THEN
        LA%(I)=0.0
      END IF
      IF LB%(I)=MRAXIS! THEN
        LB%(I)=0.0
      END IF
    NEXT I

    !===== RESTRICTION CHECK =====
    !===== HORIZONTAL FIELD SIZE =====
    J=LEAFNUM-1
    FOR I=0 TO J
      IF LA%(I) > MAXMLCFLD! THEN
        LA%(I)=MAXMLCFLD!
        OPTERRFLAG = -77
      END IF
      IF LA%(I) < -MINMLCFLD! THEN
        LA%(I)=-MINMLCFLD!
        OPTERRFLAG = -77
      END IF
      IF LB%(I) > MINMLCFLD! THEN
        LB%(I)=MINMLCFLD!
        OPTERRFLAG = -77
      END IF
      IF LB%(I) < -MAXMLCFLD! THEN
        LB%(I)=-MAXMLCFLD!
        OPTERRFLAG = -77
      END IF
    NEXT I

    !===== VERTICAL FIELD SIZE =====
    MLCMAXVER! = HLEAFNUM!*LEAFWID!
    FLDMAXVER! = CCWY%(0)
    FLDMINVER! = CCWY%(0)
    FOR I = 0 TO FLDPTNUM
      IF CCWY%(I) > FLDMAXVER! THEN
        FLDMAXVER! = CCWY%(I)
      END IF
      IF CCWY%(I) < FLDMINVER! THEN
        FLDMINVER! = CCWY%(I)
      END IF
    NEXT I
    IF FLDMAXVER! > MLCMAXVER! OR FLDMINVER! < -MLCMAXVER! THEN
      IF OPTERRFLAG = -77 THEN
        OPTERRFLAG = -99
      ELSE
        OPTERRFLAG = -88
      END IF
    END IF
    IF FLDMINVER! > MLCMAXVER! OR FLDMAXVER! < -MLCMAXVER! THEN
      OPTERRFLAG = -100
    END IF

    !===== CHECK MAX DIFFERENCE AMONG LEAVES =====

    J = LEAFNUM - 1
    LAFLU$! = LA%(0)
    LAMINUS! = LA%(0)
    LBFLU$! = LB%(0)
    LBMINUS! = LB%(0)

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FOR I = 1 TO J
  IF LA(I) > LAPLUS! THEN
    LAPLUS! = LA(I)
  END IF
  IF LA(I) < LAMINUS! THEN
    LAMINUS! = LA(I)
  END IF
  IF LB(I) > LBPLUS! THEN
    LBPLUS! = LB(I)
  END IF
  IF LB(I) < LBMINUS! THEN
    LBMINUS! = LB(I)
  END IF
NEXT I

LADIFF! = LAPLUS! - LAMINUS!
LBDIFF! = LBPLUS! - LBMINUS!

IF LADIFF! >= MAXMLCDIF! OR LBDIFF! >= MAXMLCDIF! THEN
  IF OPTERRFLAG = -77 THEN
    OPTERRFLAG = -377
  ELSEIF OPTERRFLAG = -88 THEN
    OPTERRFLAG = -388
  ELSEIF OPTERRFLAG = -99 THEN
    OPTERRFLAG = -399
  ELSEIF OPTERRFLAG = -100 THEN

    ELSE
      OPTERRFLAG = -33
    END IF
  END IF

  IF LADIFF! > MAXMLCDIF! THEN
    FOR I = 0 TO J
      DIFF! = LAPLUS! - LA(I)
      IF DIFF! > MAXMLCDIF! THEN
        LA(I) = LAPLUS! - MAXMLCDIF!
      END IF
    NEXT I
  END IF
  IF LBDIFF! > MAXMLCDIF! THEN
    FOR I = 0 TO J
      DIFF! = LB(I) - LBMINUS!
      IF DIFF! > MAXMLCDIF! THEN
        LB(I) = LBMINUS! + MAXMLCDIF!
      END IF
    NEXT I
  END IF

  *===== ASSIGN THE OPTIMIZED POSITION TO LEAF DATA =====
  FOR I=0 TO LEAFNUM-1
    AXDATA(I,I)=LA(I)
    AXDATA(I,I)=LA(I)+LEAFLEN!
    AXDATA(I,2,I)=LA(I)+LEAFLEN!
    AXDATA(I,3,I)=LA(I)
    AXDATA(I,4,I)=LA(I)

    BXDATA(I,I)=LB(I)
    BXDATA(I,I)=LB(I)-LEAFLEN!
    BXDATA(I,2,I)=LB(I)-LEAFLEN!
    BXDATA(I,3,I)=LB(I)
    BXDATA(I,4,I)=LB(I)
  NEXT I
  ERASE LA!, LB!, CCWX!, CCWY!, LA2!, LB2!
END SUB

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* (=====)

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* SUBROUTINE:

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' AUTOUNDER ()
'
' SYNOPSIS:
' INCLUDE comrocs.inc
' INCLUDE comie.inc
SUB AUTOUNDER STATIC
3000
'
' DESCRIPTION:
' This subroutine carry out geometric underblocked optimization
' for MLC field automatically
'
' ASSUMPTIONS:
' This subroutine assumes valid input variables.
'
' GLOBAL_VARIABLES:
' CONTSHIFTX! 1 MLC offset in X-dir. (cm)
' MLCFLAG 1 MLC field editor is on (0=no, 1=yes)
' MLCOPTIMODE 1 Indicate type of fit (1=auto/2=manual)
' OLDSHIFTX! 1 MLC offset in X-dir. (cm)
'
' FILES_USED:
' None
'
' SUBROUTINES_CALLED:
' DISDATA Display isodose/phantom headings and data
' DRWFLD Draw field outline and MLC
' MFLDDATA Get collimator opening and field outline for MLC field
' MLCINI Set MLC dimension and initial leaf position
' MLCOPTUNDER Search geometrically underblocked MLC leaf position
'
' AUTHOR:
' Syong Kim
'
' REVISION_HISTORY:
'
' !=====
' !
' OLDSHIFTX!=CONTSHIFTX!
' IF MLCFLAG = 1 THEN
' CALL MLCINI
' CALL MLCOPTUNDER
' MLCOPTIMODE = 1
' CALL MFLDDATA
' CALL DRWFLD
' CALL DISDATA
' ELSE
' OS.Sound 261, 2
' END IF
' CONTSHIFTX!=OLDSHIFTX!
END SUB

' !=====
' !
' SUBROUTINE:
' AUTOOVER ()
'
' SYNOPSIS:
' INCLUDE comrocs.inc
' INCLUDE comie.inc
SUB AUTOOVER STATIC
3100
'
' DESCRIPTION:
' This subroutine carry out geometric overblocked optimization
' for MLC field automatically
'
' ASSUMPTIONS:

```

```

' This subroutine assumes valid input variables.
'
' GLOBAL_VARIABLES:
'   CONTSHIFTX!  I MLC offset in X-dir. (cm)
'   MLCFLAG      I MLC field editor is on (0=no, 1=yes)
'   MLCOPTMODE    I Indicate type of fit (1=auto/2>manual)
'   OLDSHIFTX!   I MLC offset in X-dir. (cm)
'
' FILES_USED:
'   None
'
' SUBROUTINES_CALLED:
'   DISDATA      Display inodes/phantom headings and data
'   DRWFELD      Draw field outline and MLC
'   MFLDDATA     Get collimator opening and field outline for MLC field
'   MLCINI       Set MLC dimension and initial leaf position
'   MLCOPTOVER   Search geometrically overblocked MLC leaf position
'
' AUTHOR:
'   Siyong Kim
'
' REVISION_HISTORY:

```

```

' =====
'
'   OLDSHIFTX!=CONTSHIFTX!
'   IF MLCFLAG = 1 THEN
'     CALL MLCINI
'     CALL MLCOPTOVER
'     MLCOPTMODE = 1
'     CALL MFLDDATA
'     CALL DRWFELD
'     CALL DISDATA
'   ELSE
'     OS.Sound 261, 2
'   END IF
'   CONTSHIFTX'=OLDSHIFTX'
'
' END SUB
' =====

```

```

' SUBROUTINE:
'   CONVERTANG ()
'
' SYNOPSIS:
'   INCLUDE comrccs.inc
'   INCLUDE comr7.inc
'
' SUB CONVERTANG STATIC
3200
'
' DESCRIPTION:
'   This subroutine convert collimator angle to degree to radian
'   and get sine, cosine values
'
' ASSUMPTIONS:
'   This subroutine assumes valid input variables.
'
' GLOBAL_VARIABLES:
'   CA!          O Cosine value of collimator angle
'   COLANGRAD!   I Collimator angle in radian
'   COLLANG!     I Collimator angle in degree
'   PI!          I Constant for pi (3.1415926536#)
'   SA!          O Sine value of collimator angle
'
' FILES_USED:
'   None
'
' SUBROUTINES_CALLED:
'   None
'
' AUTHOR:
'   Siyong Kim

```

```

*
* REVISION_HISTORY:
*
* =====
*
COLANGRAD:=COLLANG*PI/180.0
SA:=SIN(COLANGRAD)
CA:=COS(COLANGRAD)
END SUB

*
* =====
*
SUBROUTINE:
  MLCGETANG ()

*
* SYNOPSIS:
*   INCLUDE controls.inc
*   INCLUDE comit.inc
*
SUB MLCGETANG STATIC
3300
*
* DESCRIPTION:
*   This subroutine get collimator angle in degree as user input
*
* ASSUMPTIONS:
*   This subroutine assumes valid input variables.
*
* GLOBAL VARIABLES:
*   B$      O Temporary string
*   COLLANG I Collimator angle in degree
*   ERRFLAG I Status of the file I/O routine
*   ROW     I Index for first row at menu box
*
* FILES USED:
*   None
*
* SUBROUTINES CALLED:
*   KYB.GetReal$ Get keyboard input in floating point format
*
* AUTHOR:
*   Siyong Kim
*
* REVISION_HISTORY:
*
* =====
*
ERRFLAG = 0
* ===== COLLIMATOR ANGLE SELECTION =====
CALL MENUCLR
LOCATE ROW + 2, 5
PRINT "Enter Collimator Angle . . . (Degree)";
LOCATE ROW, 3
PRINT USING "ENTER<<#.#>"; COLLANG!

* ===== User input =====
LOCATE ROW, 16
B$ = KYB.GetReal$(1)

IF B$ <> "" THEN
  SELECT CASE B$
    CASE "ESC"
      ERRFLAG = -99
      EXIT SUB
    CASE "RET"

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      CASE ELSE
        COLLANG! = VAL(B5)
      END SELECT
    END IF
    EXIT SUB
  END SUB
=====
* SUBROUTINE:
* MLCSHIFTX ()
*
* SYNOPSIS:
*   INCLUDE conrct.inc
*   INCLUDE conir.inc
*
SUB MLCSHIFTX STATIC
3400
*
* DESCRIPTION:
*   This subroutine get MLC offset in X-dir. as user input
*
* ASSUMPTIONS:
*   This subroutine assumes valid input variables.
*
* GLOBAL_VARIABLES:
*   B5          O Temporary string
*   CALPTNUM    I Number of calculation points
*   COLLANG!    I Collimator angle in degree
*   CONTSHIFTX! I MLC offset in X-dir. (cm)
*   ERRFLAG     M Status of the file I/O routine
*   FLDEEDGE()  I Irregular field outline coordinates (cm*100)
*   IRCALFT()   O X-Y coord. of calculation points
*   OLDSHIFTX!  I MLC offset in X-dir. (cm)
*   ROW         I Index for first row in menu box
*   XMAG(I)     O X-coord. for field outline with offset (cm)
*   XORG(I)     O Original X-coord. for field outline (cm)
*   XX!        O X-coord. for shifted cal. point
*
* FILES_USED:
*   None
*
* SUBROUTINES_CALLED:
*   KYB.GetReal$ Get keyboard input in floating point format
*
* AUTHOR:
*   Siyoung Kim
*
* REVISION_HISTORY.
*
=====
*
ERRFLAG = 0
* ===== CONTOUR SHIFT =====
CALL MENUCLR
LOCATE ROW + 2, 5
PRINT "Enter Contour Shift in X-dir ... (cm)";
LOCATE ROW, 3
PRINT USING "ENTER.<+###.##>"; CONTSHIFTX!

OLDSHIFTX! = CONTSHIFTX!

* ===== User input =====
LOCATE ROW, 16
B5 = KYB.GetReal$(1)

IF B5 <> "" THEN
  SELECT CASE B5

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      CASE "ESC"
        ERRFLAG = -99
        EXIT SUB

      CASE "RET"

      CASE ELSE
        CONTSHIFTX! = VAL(B$)
      END SELECT
    END IF

    ===== SHIFT CONTOUR =====
    FOR I=0 TO FLDPTNUM
      XORG!=FLDEEDGE(I,0)*0.01  *XORG!: ORIGINAL CONTOUR DATA
      XMAG!(I)=XORG!+CONTSHIFTX! *MAG!: PROJECTED AND SHIFTED
    NEXT I

    ===== SHIFT CAL. POINT =====
    FOR I = 1 TO CALPTNUM
      XX! = IRCALPT(I,0)*0.01 - OLDSHIFTX! + CONTSHIFTX!
      IRCALPT(I,0) = CINT(XX!*100)
    NEXT I

    ===== FIX SHIFT =====
    OLDSHIFTX! = CONTSHIFTX!

  END SUB
' =====
'
' SUBROUTINE:
'   MLCSHIFTY ()
'
' SYNOPSIS:
'   INCLUDE comcon.inc
'   INCLUDE comir.inc
'
' SUB MLCSHIFTY STATIC
'3500
'
' DESCRIPTION:
'   This subroutine get MLC offset in Y-dir. as user input
'
' ASSUMPTIONS:
'   This subroutine assumes valid input variables.
'
' GLOBAL_VARIABLES:
'   BS      O Temporary string
'   CALPTNUM  I Number of calculation points
'   COLLANG!  I Collimator angle in degree
'   CONTSHIFTY!  I MLC offset in Y-dir. (cm)
'   ERRFLAG   M Status of the file I/O routine
'   FLDEEDGE()  I Irregular field outline coordinates (cm*100)
'   IRCALPT()  O X-Y coord. of calculation points
'   OLDSHIFTY!  I MLC offset in Y-dir. (cm)
'   ROW       I Index for first row in menu box
'   YMAQ(O)    O Y-coord. for field outline with offset (cm)
'   YORG!      O Original Y-coord. for field outline (cm)
'   YY!        O X-coord. for shifted cal. point
'
' FILES_USED:
'   None
'
' SUBROUTINES_CALLED:
'   KYB GetReal$  Get keyboard input in floating point format
'
' AUTHOR:
'   Siyong Kim
'
' REVISION_HISTORY:

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' =====
'
ERRFLAG = 0
' ===== CONTOUR SHIFT =====
CALL MENUCLR
LOCATE ROW + 2, 5
PRINT "Enter Contour Shift in Y-dir . (cm)";
LOCATE ROW, 3
PRINT USING "ENTER:<+##.#>"; CONTSHIFT!

OLDSHIFT! = CONTSHIFT!

' ===== User input =====
LOCATE ROW, 16
B$ = KEY GetReal$(1)

IF B$ <> "" THEN

    SELECT CASE B$

        CASE "ESC"
            ERRFLAG = -99
            EXIT SUB

        CASE "RET"

        CASE ELSE
            CONTSHIFT! = VAL(B$)
    END SELECT
END IF

' ===== SHIFT CONTOUR =====
FOR I=0 TO FLDPTNUM
    YORG=(FLDEDGE(I,1)*0.01)
    YMAG(I)=YORG+CONTSHIFT! : YMAG! = SHIFTED
NEXT I
' ===== SHIFT CAL. POINT =====
FOR I = 1 TO CALPTNUM
    YY! = IRCALPT(I,1)*0.01 - OLDSHIFT! + CONTSHIFT!
    IRCALPT(I,1) = CINT(YY*100!)
NEXT I

END SUB
' =====
'
' SUBROUTINE:
' MPLDDATA ()
'
' SYNOPSIS:
'   INCLUDE comrocs.inc
'   INCLUDE comir.inc
'
SUB MPLDDATA STATIC
3600
'
' DESCRIPTION:
'   This subroutine get collimator opening, field outline and
'   calculation point location for MLC field
'
' ASSUMPTIONS:
'   This subroutine assumes valid input variables.
'
' GLOBAL VARIABLES:
'   AXDATA(I)   I X-coordinate data of leaf A
'   AYDATA(I)   I Y-coordinate data of leaf A
'   BXDATA(I)   I X-coordinate data of leaf B
'   BYDATA(I)   I Y-coordinate data of leaf B

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CA!      O Cosine value of collimator angle
CALPTNUM I Number of calculation points
COLCENTER(O) O X-Y coord. of collimator center (cm)
COLLEN!  O Collimator opening length (cm)
COLWID!  O Collimator opening width (cm)
FLDEEDGE! I Irregular field outline coordinates (cm*100)
FLDPTNUM I Number of vertices in field outline
IRCALPT(O) O X-Y coord. of calculation points
IMLCSAVE I Save MLC field or not (0=no, 1=yes),
           for 0, only collimator center is calculated
LEAFNUM  O Number of leaves in one side (26 for Varian, 40 for Philips)
MLCMAG!  O Mag. for projection of MLC from 100cm to surface
SA!      O Sine value of collimator angle

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LOCAL_VARIABLES:

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CCWCPX!  O X-coord. of rotated calculation point (cm)
CCWCPY!  O Y-coord. of rotated calculation point (cm)
CPX!     O X-coord. of original calculation point (cm)
CPY!     O Y-coord. of original calculation point (cm)
DETMAG!  O Mag. for de-projection from 100cm to surface
LEAFMAX! O Most right leaf position
LEAFMIN! O Most left leaf position
OPEN1    O Lowest leaf ID opened
OPENF    O Highest leaf ID opened

```

FILES_USED:

```

None

```

SUBROUTINES_CALLED:

```

CONVERTANG Convert collimator angle in degree to radian
            and get sine, cosine values

```

AUTHOR

```

Siyong Kim

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REVISION_HISTORY:

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```

!===== FIND OPENED PAIR OF LEAF =====
FOR I = 0 TO LEAFNUM-1
  IF BXDATA%(0,I) <> AXDATA%(0,I) THEN
    OPEN1 = I
    GOTO OPEN1
  END IF
NEXT I
OPEN1:
J = LEAFNUM - I
FOR I = 0 TO J
  IF BXDATA%(0,J-I) <> AXDATA%(0,J-I) THEN
    OPENF = J-I
    GOTO OPEN2
  END IF
NEXT I
OPEN2:
DETMAG%=1/MLCMAG!

!===== SET COLLIMATOR =====
LEAFMIN! = BXDATA%(0,OPEN1)
LEAFMAX! = AXDATA%(0,OPEN1)
FOR I = OPEN1+1 TO OPENF
  IF BXDATA%(0,I) < LEAFMIN! THEN
    LEAFMIN! = BXDATA%(0,I)
  END IF
  IF AXDATA%(0,I) > LEAFMAX! THEN
    LEAFMAX! = AXDATA%(0,I)
  END IF
NEXT I
LEAFMIN! = LEAFMIN! * DETMAG!
LEAFMAX! = LEAFMAX! * DETMAG!
COLWID! = LEAFMAX! - LEAFMIN!

```

```

COLLEN1 = (AYDATA1(3,OPENF) - AYDATA1(0,OPENI))*DEMAQ!
COLCENTER1(0) = LEAFMAX1 - 0.5*COLWID1
COLCENTER1(1) = AYDATA1(3,OPENF)*DEMAQ! - 0.5*COLLEN1
COLWID1 = COLWID1 + 1.6!
COLLEN1 = COLLEN1 + 4!

IF IMLCSAVE = 0 THEN
  EXIT SUB
END IF

!===== FIELD OUTLINE =====!
FLDPTNUM = (OPENF-OPENI+1)*4-I
REDIM FLDEEDGE(FLDPTNUM,2)

I = 0
J = 1
FOR K = OPENI TO OPENF
  FLDEEDGE(I,0) = CINT(BXDATA1(0,K)*100!)
  FLDEEDGE(I,1) = CINT(BYDATA1(0,K)*100!)
  I = I + 2
  FLDEEDGE(J,0) = CINT(BXDATA1(3,K)*100!)
  FLDEEDGE(J,1) = CINT(BYDATA1(3,K)*100!)
  J = J + 2
NEXT K

KK = OPENF + OPENI
FOR K = OPENI TO OPENF
  FLDEEDGE(I,0) = CINT(AXDATA1(3,KK-K)*100!)
  FLDEEDGE(I,1) = CINT(AYDATA1(3,KK-K)*100!)
  I = I + 2
  FLDEEDGE(J,0) = CINT(AXDATA1(0,KK-K)*100!)
  FLDEEDGE(J,1) = CINT(AYDATA1(0,KK-K)*100!)
  J = J + 2
NEXT K

!===== CONVERT CAL. POINT OPPOSITE TO COLLIMATOR ANGLE =====!
IF COLLANG1 < 0.0 THEN
  IF CALPTNUM > 0 THEN
    CALL CONVERTANG
    FOR I = 1 TO CALPTNUM
      CPX1 = IRCALPT(I,1)*0.01
      CPY1 = IRCALPT(I,1)*0.01
      CCWCPX1 = CPX1*CA1 + CPY1*SA1
      CCWCPY1 = CPY1*CA1 - CPX1*SA1
      IRCALPT(I,0) = CINT(CCWCPX1*100!)
      IRCALPT(I,1) = CINT(CCWCPY1*100!)
    NEXT I
  END IF
END IF

END SUB

* [=====
*
* SUBROUTINE:
*   SAVEMFLD ()
*
* SYNOPSIS:
*   INCLUDE comrocs.inc
*   INCLUDE comsr.inc
*   INCLUDE comtr3.inc
*
* SUB SAVEMFLD STATIC
* 3700
*
* DESCRIPTION:
*   This subroutine prompts the user to save MLC field data. If the
*   user chooses to save the data the MLC data file and the lrrag
*   library file is updated.
*
* ASSUMPTIONS:

```

This subroutine assumes valid input variables.

GLOBAL_VARIABLES:

AXDATA() I X-coordinate data of leaf A
 BEAMTYPE I 0=photon; 1=Co-60; 2=electron
 BXDATA() I X-coordinate data of leaf B
 CALPTNUM I Number of calculation points
 COLLANG I Collimator angle in degree
 COLCENTER() I X - Y coordinate of collimator center (cm)
 COLLEN I Collimator length (cm)
 COLWID I Collimator width (cm)
 CONTSHIFTX I MLC offset in X-dir. (cm)
 CONTSHIFTY I MLC offset in Y-dir. (cm)
 DATADIR I Directory pointer to a specific patient
 DATADRV I Drive pointer to patient data storage
 DATAPATH I Path pointer to patient data storage
 DEPTH() I Isoline depths
 DRVS O Name of the drive where FILES can be found
 EDGECODE() I Edge code
 EDITMODE I Beam calculation status flag
 ENERGY I Nominal energy (Mev)
 ERRFLAG O Status of the file I/O routine
 FIELDS M Number of irregular fields stored
 FILES O Temporary pointer to all library filenames
 FLDEGEO I Irregular field outline coordinates (cm * 100)
 FLDPNTNUM I Number of vertices in field outlines
 IFLDNUM O Current irregular field number
 IRCALPT I X-Y coord. of collimator points (temp array)
 IMLCSAVE I Save MLC field or not (0=no, 1=yes),
 for 0, only collimator center is calculated
 LEAFNUM O Number of leaves in one side (26 for Varian, 40 for Philips)
 MAG I Field magnification factor
 MFLAG I MLC field exists (N=no, V=Varian, P=Philips)
 MLCFLAG I MLC field editor is on (0=no, 1=yes)
 MLCMAG O Mag. for projection of MLC from 100cm to surface
 MLCYPE O Type of MLC (1 = Varian, 2 = Philips)
 ROW I Index for first row in menu box
 PATHS O Name of the path where FILES can be found
 PORTDESS I Port designation label
 ROW I Index for first row in menu box
 SITES() I Calc point label
 SSD() I Source to skin distance for each calc point
 SSDSAD I SSD/SAD distance (cm)
 SSDSADMODE I 0 = SSD beam, 1 = SAD beam
 TRAYFAC I Tray factor
 TRTUNT I Treatment unit
 TRTUNTNUM I Treatment unit file pointer
 WDGANG I Wedge angle (degrees)
 WDGORN I Wedge orientation

FILES_USED:

C D: DATAPATHSDATADIR IFLD## DAT Irregular field shape coord.
 C D: DATAPATHSDATADIR MFLD## DAT MLC field shape coord.

SUBROUTINES_CALLED:

KYB.GetStrInclude\$ Retrieves a string of MaxLen length. Enables
 specified keys with ASCII code 32-126. Also,
 could return RET or ESC string.
 MENUCLR Clear menu/command area & display time/version
 & title
 MFLDDATA Gets collimator opening, field outline and
 calculation point location for MLC field
 GETIFLD2 Gets irregular field data from the file

AUTHOR:

Siyong Kim

REVISION_HISTORY:

=====

```

*1
ERRFLAG = 0
IF EDITMODE = 1 AND MLCFLAG = 1 THEN
    CALL MENUCLR
    LOCATE ROW + 2, 10
    PRINT "Save changes? (Y or N)";
    LOCATE ROW, 3
    PRINT "ENTER <Y>";

    SELECT CASE KYB.GetString$( "YyNs", 1)

        CASE "ESC", "N", "n"
            ERRFLAG = -99
            EXIT SUB

        CASE ELSE

    END SELECT

    CALL MENUCLR
    LOCATE ROW + 2, 10
    IF MFLAG$ = "N" THEN
        PRINT "Overwrite old? (Y or N) - NO MLC Field exist";
    ELSE
        PRINT "Overwrite old? (Y or N)";
    END IF
    LOCATE ROW, 3
    IF MFLAG$ = "N" THEN
        PRINT "ENTER <Y>";
    ELSE
        PRINT "ENTER <N>";
    END IF

    SELECT CASE KYB.GetString$( "YyNs", 1)
        CASE "ESC"
            ERRFLAG = -99
            EXIT SUB

        CASE "y", "Y"
            OVERWRITE = 1

        CASE "RET"
            IF MFLAG$ = "N" THEN
                OVERWRITE = 1
            ELSE
                OVERWRITE = 0
                OROFDNUM = IFLDNUM
                IFLDNUM = FIELDS + 1
            END IF

        CASE ELSE
            OVERWRITE = 0
            OROFDNUM = IFLDNUM
            IFLDNUM = FIELDS + 1

    END SELECT
END IF

IF MLCTYPE = 1 THEN
    MFLAG$ = "Y"
ELSEIF MLCTYPE = 2 THEN
    MFLAG$ = "P"
END IF

'===== SAVE MLC FIELD =====
IMLSAVE = 1
CALL MFLDDATA
IMLSAVE = 0
CALL DisplayBusyMessage( "Saving MLC field data ..." )

IS = MID$(STR$(IFLDNUM), 2, LEN(STR$(IFLDNUM)))

```

```

IF LEN(I$) < 2 THEN
  I$ = "0" + I$
END IF
DRVS = DATADRV$
PATH$ = DATAPATH$ + DATADIR$
MFILE$ = "MFLD" + I$ + ".DAT"

IF ( OpenFile( DRVS, PATH$, MFILE$, OUTPUTMODE$, 3 ) <> SUCCESS ) THEN
  CALL ERR_Warning( "File Access", "Irreg:SaveMFlid",
    "Cannot write " + Drv$ + Path$ + File$ )
  EXIT SUB
END IF

DEMACG! = 1/MLCMAG!

PRINT #3, USING "V", PORTDESS
PRINT #3, USING "### 0 000 0 +000 00 +00 00 +00 0 +00 0 +00 0 00 00"; COLWID!, COLLEN!, COLCENTER!(0),
COLCENTER!(1), COLLANG!, CDNTSHIFT!, CDNTSHIFTY!, MLCMAG!
PRINT #3, USING "###"; LEAPNUM
FOR I = 0 TO LEAPNUM-1
  PRINT #3, USING "+000 00 +00 00"; AXDATA!(0,I)*DEMACG! BXDATA!(0,I)*DEMACG!
NEXT I
PRINT #3, USING "###"; FLDPNTNUM
IF FLDPNTNUM > 0 THEN
  FOR I = 0 TO FLDPNTNUM
    EDGECD(I) = 1
    PRINT #3, USING "+0000 +0000 0"; FLDEEDGE(I, 0); FLDEEDGE(I, 1); EDGECD(I)
  NEXT I
END IF
PRINT #3, USING "###"; CALPTNUM
FOR I = 1 TO CALPTNUM
  PRINT #3, USING "V"; SITES(I)
  PRINT #3, USING "+0000 +0000 00 000 00"; IRCALPT(I, 0); IRCALPT(I, 1); DEPTH(I); SSD(I)
NEXT I
CloseFile 3

* ===== UPDATE IRREGULAR FIELD LIBRARY =====

* ===== CHANGE VARIABLE NAME FOR MLC =====
MCDLWID! = CDLWID!
MCOLLEN! = COLLEN!
MCALEPTNUM = CALPTNUM
* =====

DRVS = DATADRV$
PATH$ = DATAPATH$ + DATADIR$
FILES = "IRREGFLD.LIB"

IF ( OpenFile( DRVS, PATH$, FILES, RANDOMMODE$, 4 ) <> SUCCESS ) THEN
  CALL ERR_Warning( "File Access", "Irreg:SaveFlid",
    "Cannot open " + Drv$ + Path$ + File$ )
  EXIT SUB
END IF

FIELD #4, 15 AS PD$, 4 AS TU$, 2 AS EY$, 2 AS BT$, 2 AS CW$,
2 AS CL$, 2 AS SS$, 2 AS SM$, 2 AS WA$, 2 AS WO$,
2 AS CP$, 10 AS ED$, 2 AS NU$,
1 AS MP$, 2 AS MCW$, 2 AS MCL$, 10 AS MED$,
2 AS MCP$

* ===== GET PARAMETER FOR BLOCK FIELD =====
GET #4, IFLDNUM
CDLWID! = CSNG(CV(IICW$))/0.1
COLLEN! = CSNG(CV(IICL$))/0.1
WDGORN = CV(IWD$)
WDGANG = CV(IWA$)
BED$ = ED$
CALPTNUM = CV(ICP$)
* =====

LSET PD$ = PORTDESS

```

```

LSET TUS = TRTUNTS
LSET EYS = MKIS(ENERGY)
LSET BTS = MKIS(BEAMTYPE)
LSET CWS = MKIS(CINT(COLWID! * 10!))
LSET CLS = MKIS(CINT(COLLEN! * 10!))
LSET SSS = MKIS(CINT(SSDSAD! * 10!))
LSET SMS = MKIS(SSOSADMODE)
LSET WOS = MKIS(WDGORN)
LSET WAS = MKIS(WDGANG)
LSET CPS = MKIS(CALPTNUM)
LSET NUS = MKIS(TRTUNTNUM)
LSET EDS = BED$
LSET MFS = MFLAG$
LSET MCWS = MKIS(CINT(MCOLWID! * 10!))
LSET MCLS = MKIS(CINT(MCOLLEN! * 10!))
LSET MEDS = DATES
LSET MCPS = MKIS(MCALPTNUM)
PUT #4, IFLDNUM
IF IFLONUM = FIELDS + 1 THEN
    FIELDS = FIELDS + 1
    LSET FDS = "-99"
    PUT #4, FIELDS + 1
END IF
CloseFile 4

'===== SAVE BLOCK FIELD FOR NO OVERWRITE CASE =====
IF OVERWRITE = 0 THEN

    '===== GET ORIGINAL BLOCK FIELD DATA =====
    OLDFLDNUM = IFLDNUM
    IFLDNUM = ORGFLDNUM
    CALL GETIFLO2
    IFLDNUM = OLDFLDNUM
    '=====

    CALL DisplayBusyMessage( "Saving block field data ..." )

    IS = MIDS(STR$(IFLDNUM), 2, LEN(STR$(IFLDNUM)))
    IF LEN(IS) < 2 THEN
        IS = "0" + IS
    END IF
    ORVS = DATADRV$
    PATHS = DATAPATH$ + DATADIRS
    '===== BLOCK FIELD DATA FILE =====
    FILES = "IFLO" + IS + ".DAT"

    IF ( OpenFile( DRV$, PATHS, FILES, OUTPUTMODE$, 3 ) <> SUCCESS ) THEN
        CALL ERR_Warning( "File Access", "Irreg.:SaveIfld",
            "Cannot write " + DRV$ + Path$ + Files )
        ERRFLAG = -99
        EXIT SUB
    END IF

    PRINT #3, USING "V", PORTDESS
    PRINT #3, USING "#####"; SSSADMODE; TRTUNTNUM; COLWIO!; COLLEN!;
    WDGANG; TRAYFAC!; COLCENTER!(0); COLCENTER!(1)
    PRINT #3, USING "#####"; MAG!; SSSAD!; FLDPTNUM
    IF FLDPTNUM > 0 THEN
        FOR I = 0 TO FLDPTNUM
            PRINT #3, USING "#####"; FLDEDGE(I, 0); FLDEDGE(I, 1); EDGECODE(I)
        NEXT I
    END IF
    PRINT #3, USING "###", CALPTNUM
    FOR I = 1 TO CALPTNUM
        PRINT #3, USING "V", SITES(I)
        PRINT #3, USING "#####"; IRCALPT(I, 0); IRCALPT(I, 1); CEPTH!(I); SSOX(I)
    NEXT I
    CloseFile 3
    '===== UPDATE IRREGULAR FIELD LIBRARY =====

    DRV$ = DATADRV$

```

```

PATH$ = DATAPATH$ + DATADIR$
FILES = "URRGGLD.LIB"

IF ( OpenFile( DRV$, PATH$, FILES, RANDOMMODE$, 4 ) <> SUCCESS ) THEN
  CALL ERR_Warning( "File Access", "Irreg::SaveIFld",
    "Cannot open " + DRV$ + Path$ + File$ )
  ERRFLAG = -99
  EXIT SUB
END IF

FIELD #4, 15 AS PD$, 4 AS TUS, 2 AS EYS, 2 AS BTS, 2 AS CWS,
  2 AS CL$, 2 AS SS$, 2 AS SM$, 2 AS WAS, 2 AS WOS,
  2 AS CP$, 10 AS ED$, 2 AS NUS,
  1 AS MP$, 2 AS MCW$, 2 AS MCL$, 10 AS MED$,
  2 AS MCP$

'GET #4, IFLDNUM
'MCOLWID! = CSNG(CV!(MCW$))*0.1
'MCOLLEN! = CSNG(CV!(MCL$))*0.1
'MCALPTNUM = CV!(MCP$)

LSET PD$ = PORTDESS
LSET TUS = TRTUNTS
LSET EYS = MKIS(ENERGY)
LSET BTS = MKIS(BEAMTYPE)
LSET CWS = MKIS(CINT(COLWID! * 10!))
LSET CL$ = MKIS(CINT(COLLEN! * 10!))
LSET SS$ = MKIS(CINT(SSDSAD! * 10!))
LSET SM$ = MKIS(SSDSADMODE)
LSET WOS = MKIS(WDGORN)
LSET WAS = MKIS(WDGANG)
LSET CP$ = MKIS(CALPTNUM)
LSET NUS = MKIS(TRTUNTNUM)
LSET ED$ = DATES
LSET MP$ = MFLAGS
LSET MCW$ = MKIS(CINT(MCOLWID! * 10!))
LSET MCL$ = MKIS(CINT(MCOLLEN! * 10!))
LSET MED$ = DATES
LSET MCP$ = MKIS(MCALPTNUM)
PUT #4, IFLDNUM
IF IFLDNUM = FIELDS + 1 THEN
  FIELDS = FIELDS + 1
  LSET PD$ = "-99"
  PUT #4, FIELDS + 1
END IF
CloseFile 4
END IF
END SUB

' =====
'
' SUBROUTINE:
' MFLDDEF ()
'
' SYNOPSIS:
' INCLUDE comrocs.inc
' INCLUDE comr.inc
' INCLUDE comr3.inc
'
SUB MFLDDEF STATIC
3800
'
' DESCRIPTION:
' This subroutine displays an MLC field based on user input.
' The user selects an MLC field and chooses to edit, load, oppose
' or export MLC fields
'
' ASSUMPTIONS:
' This subroutine assumes valid input variables.
'
' GLOBAL VARIABLES:

```

ASYCOL O Asymetric collimator used
 B\$ O Temporary string
 BEAMTYPE I 0=photon, 1=Co-60, 2=electron
 C\$ I Input string (modified by STRIP)
 CALCFLAG O 0=plan not calculated, 1=plan calculated
 CALPTNUM O Number of calculation points
 CHCS\$ O An array of character strings which make up main menu
 COLCENTER(I) O X - Y coordinate of collimator center (cm)
 COLFLAG O Collimator defined (0=no, 1=yes)
 DATADIR\$ I Directory pointer to a specific patient
 DATA DRV\$ I Drive pointer to patient data storage
 DATA PATH\$ I Path pointer to patient data storage
 DECAFAC\$ O Isoline decay factor
 DEPTH(I) O Isoline depths
 DPHFLAG O Are depths defined (0=no, 1=yes)
 DRV\$ O Name of the drive where FILES can be found
 EDITMODE O Beam calculation status flag
 ENERGY I Nominal energy (Mev)
 ERRFLAG M Status of the file I/O routine
 FIELDS O Number of irregular fields stored
 FILES O Temporary pointer to all library filenames
 FLDPTNUM O Number of vertices in field outlines
 IFLDFLAG O Field loaded? (0=no, 1=yes)
 IFLDNUM O Current irregular field number
 IMLCSAVE I Save MLC field or not (0=no, 1=yes).
 for 0, only collimator center is calculated
 MFLAG\$ I MLC field exists (N=no, V=Varian, P=Philips)
 MLCTYPE O Type of MLC (1 = Varian, 2 = Philips)
 NEXTSUB O Pointer to default menu item
 NORMFLAG O Ptns normalized (0=no, 1=yes)
 PATH\$ O Name of the path where FILES can be found
 PATNAMES I Patient name
 PORTDESS O Port designation label
 ROW I Index for first row in menu box
 SPD(I) O Source to point distance for each calc point
 SSD(I) O Source to skin distance for each calc point
 SSDSAD! I SSD/SAD distance (cm)
 SSDSADMODE I 0 = SSD beam, 1 = SAD beam
 SSDSADMODE\$ O SSD/SAD mode label
 TOPPOINT O Pointer to first record on screen
 TRAYFAC! O Tray factor
 TRTFLAG O Treatment unit defined? (0=no, 1=yes)
 TRTUNITS I Treatment unit
 TRTUNTNUM O Treatment unit file pointer
 WDGANG O Wedge angle (degrees)
 WDGORN O Wedge orientation

 FILES_USED:

 SUBROUTINES_CALLED:
 CALVIEWPORT Calculates the viewport for the graphics screen
 DECAY Calculate isotope decay factor
 DISDATA Display misc. data on graph screen
 DISPIPG Display 1 page of calculation points
 DRWIPLD Draw irregular field
 ERR menu\$ Display error message on line 5 of menu area
 GETCALIBR Get treatment unit calibration file
 GETIFLD Get irregular field
 HEADING Print screen title in reverse video on row 1
 IR7 MLC field editor
 KYB.GetSpecForm\$ Get keyboard input in specified format
 KYB.PAGEKeysOFF Disable PGUP and PGDN keys
 KYB.PAGEKeysON Enable the paging keys (PGUP, PGDN).
 MLCIPAGE Displays one page of MLC beam information
 MLCSELECT Selects MLC type
 MLCEXPORTV Creates export file containing various MLC field data
 MLCOPPOSE Creates opposed MLC field
 PAGEDN Keeps track of page information and file pointer
 information and displays the next page
 if there is one
 PAGEUP Keeps track of page information and file pointer

```

information and displays the previous page
if there is one
SETVIEWPORT HALO function, sets active viewport
STRIP Searches input string BS FOR ".,:;@,<,+," and
spaces. Returns everything up to and after
delimiter & ASCII value

AUTHOR:
Siyong Kim

REVISION_HISTORY:
=====
!
!
MNFLD0:
IFLDFLAG = 0
CALCFLAG = 0
TRTFLAG = 0
COLFLAG = 0
DMIFLAG = 0
NORMFLAG = 0
FLDPTNUM = 0
PORTDESS = ""
CALPTNUM = 0
WDGANG = 0
TRAYTAC! = !
COLCENTER(N0) = 0!
COLCENTER%(1) = 0!
ASYCOL = 0
IRPAGE = 1
IMLCSAVE = 0
' ===== OPEN FIELD LIBRARY =====

DRVS = DATADRV$
PATH$ = DATAPATH$ + DATADIR$
FILES = "IRREGFLD.LIB"

IF ( OpenFile( Dev$, Path$, File$, RANDOMMODES, 4 ) <> SUCCESS ) THEN
CALL ERR Warning( "File Access", "Irreg:IFldDef"...
"Cannot open " + Dev$ + Path$ + File$ )
EXIT SUB
END IF

'trv-4
FIELD #4, 15 AS PDS, 4 AS TUS, 2 AS EYS, 2 AS RTS, 2 AS CWS,...
2 AS CLS, 2 AS SSS, 2 AS SMS, 2 AS WAS, 2 AS WOS,...
2 AS CPS, 10 AS ED$, 2 AS NUS,...
1 AS MFS, 2 AS MCWS, 2 AS MCLS, 10 AS MED$,...
2 AS MCP$

'trv-f
NUMRECS = LOP(4) / 128
FOR FIELDS = 1 TO NUMRECS
GET #4, FIELDS
IF LEFT$(PDS, 3) = "-99" THEN
EXIT FOR
END IF
NEXT FIELDS
FIELDS = FIELDS - 1
IF FIELDS = -1 THEN
LSET POK$ = "-99"
PUT #4, 1
FIELDS = 0
END IF
IF FIELDS = 0 THEN
OS.Sound 261, 2
EXIT SUB
END IF
' ===== DISPLAY IRREGULAR FIELD LIBRARY =====
MNFLD$:
TITLES = " IRREGULAR FIELDS FOR " + PATNAMES + " "
CLS
CALL HEADNG( TITLES )

```

```

LOCATE 2, 1
PRINT " # FIELD      UNIT Mv COL SET SSD/SAD WDG  CALC  LAST  MLC";
LOCATE 3, 1
PRINT "              WxL(cm)  (cm) ANG POINTS  UPDATE  Var,Phi";
TOPPOINT = 1
POINTER = 1

IFLDNUM = FIELDS
CALL IRIPAGE
CALL MLCIPAGE
ERASE CHCS
CHCS(0) = " MLC FIELD EDITOR "
MNFLD3:
CALL MENUCLR
LOCATE ROW + 1, 10
PRINT " #_Field # to be loaded.";
LOCATE ROW + 2, 10
PRINT " #E_ Field # to be edited.";
LOCATE ROW + 3, 10
PRINT " #O_ Field # to be opposed ";
LOCATE ROW + 1, 50
PRINT " X_Export MLC Fields;";
LOCATE ROW + 2, 50
PRINT " L_Import MLC Fields;";

MNFLD2:

IRPAGE = 1
EDITMODE = 0

DO
  IF IFLDNUM > 15 THEN
    LOCATE ROW + 3, 59
    PRINT "PgUp PgDn";
    CALL KYB PAGEKeysON
  END IF

  LOCATE ROW, 3
  PRINT USING "ENTER:<##>"; IFLDNUM;
  B$ = KYB GetSpecForm$( "{Xs0123456789}({#})[,|EeOo]})" )
  CALL KYB PAGEKeysOff

  SELECT CASE B$

    CASE "PGUP"
      CALL PAGEUP

    CASE "PGDN"
      CALL PAGEDN

    CASE "ESC"
      CloseFile 4
      EXIT SUB

    CASE "RET"
      B$ = ""
      GOTO MNFLD4

    CASE "x", "X"
      CALL MLCSELECT
      IF ERRFLAG = -99 THEN
        ERRFLAG = 0
        GOTO MNFLD3
      END IF
      IF MLCTYPE = 1 THEN
        OLDDATADRV$ = DATADRV$
        OLDDATAPATH$ = DATAPATH$
        OLDDATADIR$ = DATADIR$
        CALL MLCEXPORT

```

```

      CloseFile 4
      DATA DRV5 = OLDDATA DRV5
      DATA PATH5 = OLDDATA PATH5
      DATA DIR5 = OLDDATA DIR5
      ELSEIF MLCTYPE = 2 THEN
        CALL MLCEXPORT
      END IF
      GOTO MNFLD0

CASE "I", "I"
  CALL MLCSELECT
  IF ERRFLAG = -99 THEN
    ERRFLAG = 0
    GOTO MNFLD3
  END IF
  IF MLCTYPE = 1 THEN
    CALL MLCIMPORTV
  ELSEIF MLCTYPE = 2 THEN
    CALL MLCIMPORTP
  END IF
  GOTO MNFLD3

CASE ELSE
  CALL STRIP

  IF VAL(C5) < 1 OR VAL(C5) > FIELDS THEN
    CALL ERR.mnu5c("INVALID FIELD NUMBER -- RE-ENTER", "", "")
    GOTO MNFLD2
  ELSE
    IFLDNUM = VAL(C5)
    B5 = RIGHTS(UCASEK(B5,I))

MNFLD4:
    GET #4, IFLDNUM
    MFLAG5 = MFS
    IF MFLAG5 = "V" THEN
      MLCTYPE = 1
    ELSEIF MFLAG5 = "P" THEN
      MLCTYPE = 2
    ELSEIF MFLAG5 = "N" THEN
      IF B5 = "" THEN
        CALL ERR.mnu5c("NO MLC FIELD -- RE-ENTER", "", "")
        GOTO MNFLD2
      ELSEIF B5 = "E" THEN
        CALL MLCSELECT
        IF ERRFLAG = -99 THEN
          ERRFLAG = 0
          GOTO MNFLD3
        END IF
      END IF
    END IF
    EXIT DO
  END IF

END SELECT
LOOP

'===== EDIT FIELD =====

IF B5 = "E" THEN
  EDITMODE = 1
END IF

'===== OPPOSED FIELD =====

IF B5 = "O" THEN
  GET #4, IFLDNUM
  TRTUNTS = TUS
  ENERGY = CVI(EYS)
  BEAMTYPE = CVI(BTS)
  WDGORN = CVI(WOS)
  WDGANG = CVI(WAS)

```

```

MFLAGS = MF$
CloseFile 4
IF MFLAGS = "N" THEN
    CALL ERR.mmm5("INVALID MLC FIELD # - RE-ENTER", "", "")
    GOTO MNFLD2
END IF
CALL MLCOPPOSE
ERRFLAG = 0
GOTO MNFLD0
END IF

' ===== LOAD IRREGULAR FIELD =====

CALL DisplayBusyMessage( "Loading field data ..." )

GET #4, IFLDNUM
TRTUNTNUM = CVI(NU$)
WDGANG = CVI(WAS)
WDGDRN = CVI(WOS)
MFLAGS = MF$

IF WDGANG <> 0 THEN
    WEDGE = TRUE
ENDIF

CloseFile 4
MNFLD1:
CALL GETCALIBR
CALL GETIBLD

IF SSDSADMODE = 0 THEN
    SSDSADMODE$ = "SSD"
ELSE
    SSDSADMODE$ = "SAD"
ENDIF

' ===== CHECK FOR EDITING =====
IF EDITMODE = 1 THEN
    CALL IR7
    EDITMODE = 0
    IF ERRFLAG = 0 THEN
        GOTO MNFLD1
    ELSE
        NEXTSUB = 2
        ERRFLAG = 0
        COLFLAG = 0
        CALLS SETVIEWPORT(0, 0, 1, 1, 1, 0, 0)
        EXIT SUB
    END IF
END IF
IF BEAMTYPE = 1 THEN
    CALL DECAY
ELSE
    DECAYFAC! = 1!
END IF

CALL CALCVIEWPORT

' ===== DRAW TEXT/GRAPHICS SCREEN =====
DEPTH/(CALPTNUM + 1) = DMAX!
IF SSDSADMODE = 0 THEN
    SSD/(CALPTNUM + 1) = SSDSAD!
ELSE
    SSD/(CALPTNUM + 1) = SSD!(1)
ENDIF
SPD/(CALPTNUM + 1) = SSD/(CALPTNUM + 1) + DEPTH/(CALPTNUM + 1)
CALLS SETVIEWPORT(0, 0, 1, 1, 1, 0, 0)
CALL DRWFLD
CALL DISDATA
TDPOINT = 1
CALL DISP1PG

```

```

IF CALPTNUM > 0 THEN
  NEXTSUB = 3
ELSE
  NEXTSUB = 6
END IF
ERRFLAG = -99
END SUB

```

```

SUBROUTINE
  GETMFLD ()

```

```

SYNOPSIS:
  INCLUDE comcnc.inc
  INCLUDE comir.inc
  INCLUDE comir3.inc

```

```

SUB GETMFLD STATIC
3900

```

```

DESCRIPTION:
  This subroutine gets MLC field data from the file

```

```

ASSUMPTIONS:
  This subroutine assumes valid input variables.

```

```

GLOBAL VARIABLES:

```

```

CALPTNUM      I Number of calculation points
COLLANGO!     I Collimator angle in degree
COLCENTER(I)  I X - Y coordinate of collimator center (cm)
COLLEN!       I Collimator length (cm)
COLWID!       I Collimator width (cm)
DATADIR$      I Directory pointer to a specific patient
DATADRV$      I Drive pointer to patient data storage
DATAPATH$     I Path pointer to patient data storage
DEPTH(I)      I Isoline depths
DRV$          O Name of the drive where FILES can be found
EDGECODE(I)   I Edge code
EDITMODE      I Beam calculation status flag
FLDEGE(I)     I Irregular field outline coordinates (cm * 100)
FLDPNTNUM     I Number of vertices in field outlines
IFLD$FLAG     O Field loaded? (0=no, 1=yes)
IFLDNUM       O Current irregular field number
IRCALPT(I)    I X-Y coord. of collimator points (temp array)
LEAFNUM       O Number of leaves in one side (26 for Varian, 40 for Phillips)
LEAFAO(I)     I Leaf position for A side
LEAFBO(I)     I Leaf position for B side
MLCMAGO!      O Mag. for projection of MLC from 100cm to surface
MLCOFFSETXO!  I MLC offset in X-dir. (cm)
MLCOFFSETYO!  I MLC offset in Y-dir. (cm)
PATH$         O Name of the path where FILES can be found
PORTDES$      I Port designation label
SITE(I)       I Calc point label
SPD(I)        I Source to point distance for each calc point
SSD(I)        I Source to skin distance for each calc point

```

```

FILES USED:
  C D: DATAPATH$ \ DATADIR$ MFLD##.DAT MLC field shape coord.

```

```

SUBROUTINES CALLED:

```

```

AUTHOR:
  Siyong Kim

```

```

REVISION HISTORY:

```

```

IS = MID$(STR$(IFLDNUM), 2, LEN$(STR$(IFLDNUM)))
IF LEN(IS) < 2 THEN

```

```

IS = "0" + IS
END IF
DRVS = DATA DRV$
PATH$ = DATA PATH$
MFILES = DATA DIR$ + "MFLD" + IS + " DAT"
MRRQ2:
IF ( OpenFile( Dev$, Path$, MFILES, INPUTMODE$, 3 ) <> SUCCESS ) THEN
CALL ERR.Warning( "File Access", "Ineg::GetMFlid",
                  "Cannot open " + Dev$ + Path$ + File$ )
EXIT SUB
END IF

INPUT #3, PORTBSS
INPUT #3, COLWID1, COLLEN1, COLCENTER1(0), COLCENTER1(1), COLLANGO1, MLCOFFSETXO1, MLCOFFSETYO1,
MLCMAGO1
INPUT #3, LEAFNUM
LEAFNUM = 26
FOR I = 0 TO LEAFNUM-1
INPUT #3, LEAFAO(I), LEAFBO(I)
NEXT I
IF EDITMODE = 0 THEN
INPUT #3, FLDPNTNUM
I = FLDPNTNUM
IF I > 0 THEN
REDIM FLDEDGE(0 TO I, 0 TO 1), EDGECDDE(0 TO I)
IF FLDPNTNUM > 0 THEN
FOR I = 0 TO FLDPNTNUM
INPUT #3, FLDEDGE(I, 0), FLDEDGE(I, 1), EDGECDDE(I)
NEXT I
IFLDFLAG = 1
END IF
END IF
ELSE
INPUT #3, DUMMYNUM
IF DUMMYNUM > 0 THEN
FOR I = 0 TO DUMMYNUM
INPUT #3, DUMMY1, DUMMY2, DUMMY3
NEXT I
END IF
END IF
INPUT #3, CALPTNUM
OLDPNTS = CALPTNUM
I = CALPTNUM + 1
REDIM IRCALPT(1 TO I, 0 TO 1), DEPTH(1 TO I), SSD(1 TO I)
REDIM SPD(1 TO I), SITES(1 TO I)
IF CALPTNUM > 0 THEN
DPHFLAG = 1
FOR I = 1 TO CALPTNUM
INPUT #3, SITES(I)
INPUT #3, IRCALPT(I, 0), IRCALPT(I, 1), DEPTH(I), SSD(I)
SPD(I) = SSD(I) + DEPTH(I)
NEXT I
END IF
CloseFile 3

'===== REVERT CAL. POINT ACCORDING TO COLLIMATOR ANGLE =====
IF EDITMODE = 0 THEN
EXIT SUB
END IF
IF COLLANGO1 <> 0.0 THEN
IF CALPTNUM > 0 THEN
CDLANGRADO1 = COLLANGO1 * PI / 180.0
SAD1 = SIN(CDLANGRADO1)
CAD1 = COS(CDLANGRADO1)
FOR I = 1 TO CALPTNUM
CPX1 = IRCALPT(I, 0) * 0.01
CPY1 = IRCALPT(I, 1) * 0.01
CCWCPX1 = CPX1 * CAD1 - CPY1 * SAD1
CCWCPY1 = CPY1 * CAD1 + CPX1 * SAD1
IRCALPT(I, 0) = CINT(CCWCPX1 * 100)

```

```

      IRCALPT(1,1) = CINT(CCWCPY)*100)
    NEXT I
  END IF
END IF

END SUB

=====
* SUBROUTINE:
*   IR7 ()
*
* SYNOPSIS:
*   INCLUDE cmrocs.inc
*   INCLUDE comr.inc
*   INCLUDE comr3.inc
*
* SUB IR7 STATIC
4000
* DESCRIPTION:
*   This subroutine is the MLC field main editing menu. Control is
*   transferred to the appropriate routine based on which function key is
*   pressed
*
* ASSUMPTIONS:
*   This subroutine assumes valid input variables.
*
* GLOBAL_VARIABLES:
*   BS          I Temporary string
*   BACKCOLOR   I Color index for background
*   BT1         O Lower viewport coordinate for current window
*   CALPTNUM    I Number of calculation points
*   CHCS()      O An array of character strings which make up main menu
*   COLLANG!    I Collimator angle in degree
*   CONTSHIFTX! I MLC offset in X-dir. (cm)
*   CONTSHIFTY! I MLC offset in Y-dir. (cm)
*   DPHFLAG     I Are depths defined (0=no, 1=yes)
*   EDITMODE    I Beam calculation status flag
*   ERKFLAG     M Status of the file I/O routine
*   FORECOLOR   I Color index for foreground
*   IFLDFLAG    I Field loaded? (0=no, 1=yes)
*   LIMITS()    D Label for active corner
*   LT1         O Left norm. device coord. for viewports current window
*   MFLAG5      I MLC field exists (N=no, V=Varnas, P=Phlips)
*   MLCOPTMODE   I Indicate type of fit (1=auto/2=manual)
*   MLCSETFLAG  I MLC is set? (0=no, 1=yes)
*   MLCSTART    I Indicates MLC edit type (1=autofit, 2=under,
*               3=over, 4=manual)
*   MXDEST1    O
*   NEXTSUB    O Pointer to default menu item
*   OPTERRFLAG  M Status of the MLC editing
*   ROW        I Index for first row in menu box
*   RT1        O Right norm. device coord. for viewports current window
*   TOPPOINT   O Pointer to first record on screen
*   TP1        O Top norm. device coord. for viewports current window
*   WDGANG     O Wedge angle (degrees)
*
* FILES_USED:
*   None
*
* SUBROUTINES_CALLED:
*   AUTDFIT      Carry out geometric optimization for MLC field
*                 automatically
*   AUTOOVER     Carry out geometric overblocked optimization for
*                 MLC field automatically
*   AUTOUNDER    Carry out geometric underblocked optimization for
*                 MLC field automatically
*   CDNVERTANG   Convert collimator angle in degree to radian
*                 and get sine, cosine values
*   D8SDATA      Display modcos/phantom headings and data

```

```

* DISP1PG      Display 1 page of calculation points
* DRWFOLD      Draw field outline
* IR3CLCPNT     Digitize calculation points
* IR3PNTDPH     Input calculation depths
* KYB.MenuSelect$ Get menu selection
* KYB.PAGEKeysOFF Disable PGUP and PGDN keys
* KYB.PAGEKeysON  Enable the paging keys (PGUP, PGDN).
* LEAFRETRIV     Set existing MLC field
* MANUFIT        Carry out geometric optimization for MLC field
*                manually
* MENUCLR        Clear menu display section
* MFLDDATA        Get collimator opening and field outline for
*                MLC field
* MLCINI         Set MLC dimension and initial leaf position
* MLCGETANG       Get collimator angle in degree
* MLCSETMENU      Displays MLC field editor menu
* MLCSHIFTX       Get MLC offset in X-dir
* MLCSHIFTY       Get MLC offset in Y-dir
* SAVEMFLD        Save MLC field data
* SETVIEWPORT     HALO function, set current view port to area
*                specified by the diagonally opposed normalized
*                device coordinate pairs
*
* AUTHOR:
*          Syong Kim
*
* REVISION_HISTORY.
*
* =====
*
* LT! = .45
* TP! = .15
* RT! = .95
* BT! = .85
* MXDIST! = 0!
* LIMITS(0) = "Lower"
* LIMITS(1) = "Upper"
* CALLS SETVIEWPORT(0!, 0!, 1!, 1!, 0, 0)
* IF EDITMODE = 1 THEN
*   IF MFLAG$ = "V" OR MFLAG$ = "P" THEN
*     CALL MLCINI
*     CALL LEAFRETRIV
*     MLCSETFLAG = 1
*     MLCOPTMODE = 1
*   ELSE
*     COLLANG! = 0!
*     CONTSHIFTX! = 0!
*     CONTSHIFTY! = 0!
*     CALL CONVERTANG
*   END IF
*   CALL DRWFOLD
*   CALL DISDATA
*   TOPONT = 1
*   CALL DISP1PG
*   NEXTSUB = 1
* END IF
*
* ===== TOP OF MENU LOOP =====
* MLCSTART = 0
* OPTIERRFLAG = 0
*
* DO
*   ERRFLAG = 0
*   IF IFLDFLAG = 1 THEN
*     CHCK(0) = " MLC FIELD EDITOR "
*   END IF
*   CALL MENUCLR
*   IF OPTIERRFLAG <> 0 THEN
*     NEXTSUB = 10
*   END IF
*   IF IFLDFLAG = 1 THEN

```

```

CALL MLCSETMENU
END IF
IF OPFLAG = 1 THEN
  IRPAGE = 0
  CALL KYB PAGEKeyON
END IF

IF OPTERRFLAG = -77 THEN
  OS.Sound 261, 2
  LOCATE ROW + 3, 10
  COLOR BACKCOLR, FORECOLR
  PRINT "LEAF REACH LIMIT"
  COLOR FORECOLR, BACKCOLR
ELSEIF OPTERRFLAG = -88 THEN
  OS.Sound 261, 2
  LOCATE ROW + 3, 10
  COLOR BACKCOLR, FORECOLR
  PRINT "FIELD OUT OF MLC"
  COLOR FORECOLR, BACKCOLR
ELSEIF OPTERRFLAG = -99 THEN
  OS.Sound 261, 2
  LOCATE ROW + 3, 10
  COLOR BACKCOLR, FORECOLR
  PRINT "LEAF REACH LIMIT & FIELD OUT OF MLC"
  COLOR FORECOLR, BACKCOLR
ELSEIF OPTERRFLAG = -100 THEN
  OS.Sound 261, 2
  LOCATE ROW + 3, 10
  COLOR BACKCOLR, FORECOLR
  PRINT "FIELD IS OUTSIDE THE MLC"
  COLOR FORECOLR, BACKCOLR
ELSEIF OPTERRFLAG = -377 THEN
  OS.Sound 261, 2
  LOCATE ROW + 3, 3
  COLOR BACKCOLR, FORECOLR
  PRINT "LEAF REACH LIMIT & MAX LEAF DIF. EXCESS LIMIT"
  COLOR FORECOLR, BACKCOLR
ELSEIF OPTERRFLAG = -388 THEN
  OS.Sound 261, 2
  LOCATE ROW + 3, 3
  COLOR BACKCOLR, FORECOLR
  PRINT "FIELD OUT OF MLC & MAX. LEAF DIF. EXCESS LIMIT"
  COLOR FORECOLR, BACKCOLR
ELSEIF OPTERRFLAG = -399 THEN
  OS.Sound 261, 2
  LOCATE ROW + 3, 3
  COLOR BACKCOLR, FORECOLR
  PRINT "LEAF REACH LIMIT, FIELD OUT OF MLC & MAX. LEAF DIF. EXCESS LIMIT"
  COLOR FORECOLR, BACKCOLR
ELSEIF OPTERRFLAG = -33 THEN
  OS.Sound 261, 2
  LOCATE ROW + 3, 3
  COLOR BACKCOLR, FORECOLR
  PRINT "MAX. LEAF DIF. EXCESS LIMIT"
  COLOR FORECOLR, BACKCOLR

END IF

OPTERRFLAG = 0

%***** USER INPUT *****%

B5 = KYB MenuSelecton5

CALL KYB.PAGEKeyOFF

SELECT CASE B5

  CASE "F1"
    MLCSETFLAG = 1
    CALL AUTOFTT

```

```

MLCSTART = 1
NEXTSUB = 1

CASE "F2"
  MLCSETFLAG = 1
  CALL AUTOUNDER
  MLCSTART = 2
  NEXTSUB = 2

CASE "F3"
  MLCSETFLAG = 1
  CALL AUTOOVER
  MLCSTART = 3
  NEXTSUB = 3

CASE "F5"
  IF MLCSETFLAG = 1 THEN
    MLCSTART = 4
  END IF
  MLCSETFLAG = 1
  CALL MANUFIT
  MLCSTART = 4
  NEXTSUB = 5

CASE "F6"
  IF WDGANG > 0 THEN
    OS Sound 261, 2
    GOTO DOOVER
  END IF
  STARTOLD = MLCSTART
  CALL MLCGETANG
  IF ERRFLAG = -99 THEN
    ERRFLAG = 0
    MLCSTART = STARTOLD
    GOTO DOOVER
  END IF
  IF MLCSTART = 1 OR MLCSTART = 0 THEN
    CALL AUTOFIT
  ELSEIF MLCSTART = 2 THEN
    CALL AUTOUNDER
  ELSEIF MLCSTART = 3 THEN
    CALL AUTOOVER
  ELSE
    CALL AUTOFIT
    MLCSTART = 1
    NEXTSUB = 1
  END IF

CASE "F9"
  CALL MLCSHIFTX
  IF ERRFLAG = -99 THEN
    ERRFLAG = 0
    GOTO DOOVER
  END IF
  MLCOPTIMODE = 1
  CALL MFLDDATA
  CALL DRWFELD
  CALL DISDATA
  CALL DISPIG

CASE "F10"
  CALL MLCSHIFTY
  IF ERRFLAG = -99 THEN
    ERRFLAG = 0
    GOTO DOOVER
  END IF
  MLCOPTIMODE = 1
  CALL MFLDDATA
  CALL DRWFELD
  CALL DISDATA
  CALL DISPIG

```

```

CASE "F7"
  IF MLCSETFLAG = 1 THEN
    CALL IR3CLCPNT
  ELSE
    OS.Sound 261, 2
  END IF

CASE "F11"
  IF CALPTNUM > 0 THEN
    CALL IR3PNTDPH
  ELSE
    OS.Sound 261, 2
  END IF

CASE "PGUP"
  CALL PAGEUP

CASE "PGDN"
  CALL PAGEDN

CASE "ESC"
IR7ESC:
  IF MLCSETFLAG = 1 THEN
    MLCSETFLAG = 0
    MLCOPTIMODE = 0
    CALL SAVEMFLD 'REV'
  ELSE
    MLCSETFLAG = 0
    MLCOPTIMODE = 0
    NEXTSUB = 1
    ERRFLAG = -99
  END IF
  EXIT SUB
DOOVER:
  END SELECT
  LOOP
END SUB

'=====
'
' SUBROUTINE:
'   ISODRW ()
'
' SYNOPSIS:
'   INCLUDE comrccs.inc
'   INCLUDE comir.inc
'   INCLUDE comir3.inc
'
' SUB ISODRW STATIC
4100
'
' DESCRIPTION:
'   This subroutine draws original isocenter before MLC offset
'
' ASSUMPTIONS:
'   This subroutine assumes valid input variables.
'
' GLOBAL_VARIABLES:
'   BAXIS!      1 Lower left Y world coordinate
'   CLROLD      1 Original color index for graphics
'   CONTSHPITY! 1 MLC offset in Y-dir. (cm)
'   LAXIS!      1 Lower left X world coordinate
'   LEAFCOLR    1 Color for MLC leaf
'   OLDSHIFTX!  1 MLC offset in X-dir. (cm)
'
' FILES_USED:
'   None
'
' SUBROUTINES_CALLED:

```

```

* INQCLR      HALO, inquire color index at (X,Y)
* LNABS      HALO function, draws a line from the current graphics
*            cursor position to the specified (X,Y) coordinates.
*            The graphic cursor position is updated to (X,Y).
* MOVABS     HALO, move graphics cursor to (X,Y)
* SETCOLOR   HALO, set active color

* AUTHOR:
* Siyong Kim

* REVISION_HISTORY:
*
* =====
*
* !===== DRAW ORIGINAL ISOCENTER BEFORE OFFSET =====
* CALLS INQCLR(LAXIS!, BAXIS!, CLROLD)
* CALLS SETCOLOR(LEAPCOLR)
*
* XI=OLDSHIFTX!-0.25
* YI=CONTSHIFTY!-0.25
* XF=OLDSHIFTX!+0.25
* YF=CONTSHIFTY!+0.25
* CALLS MOVABS(XI!,CONTSHIFTY!)
* CALLS LNABS(XF!,CONTSHIFTY!)
* CALLS MOVABS(OLDSHIFTX!,YI!)
* CALLS LNABS(OLDSHIFTX!,YF!)
*
* CALLS SETCOLOR(CLROLD)
*
* END SUB
*
* =====
*
* SUBROUTINE:
* LEAFINI ()
*
* SYNOPSIS:
* INCLUDE comrocs.inc
* INCLUDE commr.inc
* INCLUDE commr3.inc
*
* SUB LEAFINI STATIC
* 4200
*
* DESCRIPTION:
* This subroutine set initial values for leaf position
*
* ASSUMPTIONS:
* This subroutine assumes valid input variables.
*
* GLOBAL_VARIABLES:
* AXDATA()  I X-coordinate data of leaf A
* AYDATA()  I Y-coordinate data of leaf A
* BXDATA()  I X-coordinate data of leaf B
* BYDATA()  I Y-coordinate data of leaf B
* HLEAFNUM! I 1/2 of number of leaves
* LEAPCOLR  I Color for MLC leaf
* LEAPLEN!  O Length of MLC leaf
* LEAFNUM   O Number of leaves in one side (26 for Varian, 40 for Philips)
* LEAPWID!  O Width of MLC leaf
*
* FILES_USED:
* None
*
* SUBROUTINES_CALLED:
*
* AUTHOR:
* Siyong Kim
*
* REVISION_HISTORY:

```

```

=====
*
*
*===== INITIALIZE LEAF DATA =====
J=LEAFNUM-1
FOR I=0 TO J
  BXDATA(0,I)=0.0
  BXDATA(1,I)=LEAFLEN*
  BXDATA(2,I)=LEAFLEN*
  BXDATA(3,I)=0.0
  BXDATA(4,I)=0.0

  AXDATA(0,I)=0.0
  AXDATA(1,I)=LEAFLEN*
  AXDATA(2,I)=LEAFLEN*
  AXDATA(3,I)=0.0
  AXDATA(4,I)=0.0
NEXT I

BYDATA(0,0)=(-HLEAFNUM)*LEAFWID*
BYDATA(1,0)=(-HLEAFNUM)*LEAFWID*
BYDATA(2,0)=BYDATA(0,0)+LEAFWID*
BYDATA(3,0)=BYDATA(0,0)+LEAFWID*
BYDATA(4,0)=(-HLEAFNUM)*LEAFWID*

AYDATA(0,0)=(-HLEAFNUM)*LEAFWID*
AYDATA(1,0)=(-HLEAFNUM)*LEAFWID*
AYDATA(2,0)=BYDATA(0,0)+LEAFWID*
AYDATA(3,0)=BYDATA(0,0)+LEAFWID*
AYDATA(4,0)=(-HLEAFNUM)*LEAFWID*

J=LEAFNUM-1
FOR I=1 TO J
  BYDATA(0,I)=BYDATA(0,I-1)+LEAFWID*
  BYDATA(1,I)=BYDATA(1,I-1)+LEAFWID*
  BYDATA(2,I)=BYDATA(2,I-1)+LEAFWID*
  BYDATA(3,I)=BYDATA(3,I-1)+LEAFWID*
  BYDATA(4,I)=BYDATA(4,I-1)+LEAFWID*

  AYDATA(0,I)=AYDATA(0,I-1)+LEAFWID*
  AYDATA(1,I)=AYDATA(1,I-1)+LEAFWID*
  AYDATA(2,I)=AYDATA(2,I-1)+LEAFWID*
  AYDATA(3,I)=AYDATA(3,I-1)+LEAFWID*
  AYDATA(4,I)=AYDATA(4,I-1)+LEAFWID*
NEXT I

END SUB

=====
*
* SUBROUTINE:
* LEAFRETRIV Q
*
* SYNOPSIS:
* INCLUDE comcrs.inc
* INCLUDE comir.inc
* INCLUDE comir3.inc
*
SUB LEAFRETRIV STATIC
4300
*
* DESCRIPTION:
* This subroutine set existing MLC field
*
* ASSUMPTIONS:
* This subroutine assumes valid input variables.
*
* GLOBAL VARIABLES:
* AXDATA(0) I X-coordinate data of leaf A
* AYDATA(0) I Y-coordinate data of leaf A
* BXDATA(0) I X-coordinate data of leaf B

```

```

BYDATA%() 1 Y-coordinate sum of leaf B
COLLANG% 1 Collimator angle in degree
COLLANGO% 1 Collimator angle in degree
CONTSHIFTX% 1 MLC offset in X-dir. (cm)
CONTSHIFTY% 1 MLC offset in Y-dir. (cm)
FLDDEG% 1 Irregular field outline coordinates (cm * 100)
FLDPTNUM 1 Number of vertices in field outlines
HLEAFNUM% 1 1/2 of number of leaves
LEAFAO% 1 Leaf position for A side
LEAFBO% 1 Leaf position for B side
LEAFLEN% 0 Length of MLC leaf
LEAFNUM 0 Number of leaves in one side (26 for Varian, 40 for Philips)
LEAFWID% 0 Width of MLC leaf
MLCMAG% 0 Mag. for projection of MLC from 100cm to surface
MLCOFFSETXO% 1 MLC offset in X-dir. (cm)
MLCOFFSETYO% 1 MLC offset in Y-dir. (cm)
XMAG% 0 X-coord. for field outline with offset (cm)
XORG% 0 Original X-coord. for field outline (cm)
YMAG% 0 Y-coord. for field outline with offset (cm)

```

FILES_USED:

None

SUBROUTINES_CALLED:

CONVERTANG Convert collimator angle in degree to radian
and get sine, cosine values

AUTHOR:

Siyong Kim

REVISION_HISTORY:

```

!=====
!
!===== GET THE OLD LEAF POSITION =====
J=LEAFNUM-1
FOR I=0 TO J
  BXDATA%(0,I)=LEAFBO%(I)*MLCMAG%
  BXDATA%(1,I)=BXDATA%(0,I)+LEAFLEN%
  BXDATA%(2,I)=BXDATA%(0,I)+LEAFLEN%
  BXDATA%(3,I)=LEAFBO%(I)*MLCMAG%
  BXDATA%(4,I)=LEAFBO%(I)*MLCMAG%

  AXDATA%(0,I)=LEAFBO%(I)*MLCMAG%
  AXDATA%(1,I)=AXDATA%(0,I)+LEAFLEN%
  AXDATA%(2,I)=AXDATA%(0,I)+LEAFLEN%
  AXDATA%(3,I)=LEAFBO%(I)*MLCMAG%
  AXDATA%(4,I)=LEAFBO%(I)*MLCMAG%

```

NEXT I

```

BYDATA%(0,0)=-(HLEAFNUM!*LEAFWID%)
BYDATA%(1,0)=HLEAFNUM!*LEAFWID%
BYDATA%(2,0)=BYDATA%(0,0)+LEAFWID%
BYDATA%(3,0)=BYDATA%(0,0)+LEAFWID%
BYDATA%(4,0)=HLEAFNUM!*LEAFWID%

AYDATA%(0,0)=-(HLEAFNUM!*LEAFWID%)
AYDATA%(1,0)=HLEAFNUM!*LEAFWID%
AYDATA%(2,0)=BYDATA%(0,0)+LEAFWID%
AYDATA%(3,0)=BYDATA%(0,0)+LEAFWID%
AYDATA%(4,0)=HLEAFNUM!*LEAFWID%

```

J=LEAFNUM-1

FOR I=1 TO J

```

  BYDATA%(0,I)=BYDATA%(0,I-1)+LEAFWID%
  BYDATA%(1,I)=BYDATA%(1,I-1)+LEAFWID%
  BYDATA%(2,I)=BYDATA%(2,I-1)+LEAFWID%
  BYDATA%(3,I)=BYDATA%(3,I-1)+LEAFWID%
  BYDATA%(4,I)=BYDATA%(4,I-1)+LEAFWID%

```

```

      AYDATA(I,J)=AYDATA(I,J-1)+LEAFWID!
      AYDATA(I,J)=AYDATA(I,J-1)+LEAFWID!
      AYDATA(I,J)=AYDATA(I,J-1)+LEAFWID!
      AYDATA(I,J)=AYDATA(I,J-1)+LEAFWID!
      AYDATA(I,J)=AYDATA(I,J-1)+LEAFWID!
NEXT I

COLLANG! = COLLANGO!
CALL CONVERTANG
CONTSHIFTX! = MLCOFFSETXO!
CONTSHIFTY! = MLCOFFSETYO!
OLDSHIFTX! = CONTSHIFTX!

===== GET THE CONTOUR =====
FOR I=0 TO FLDPNTNUM
  XORG!=FLDEDGE(I,0)*0.01  'XORG!: ORIGINAL CONTOUR DATA
  YORG!=FLDEDGE(I,1)*0.01
  XMAG(I)=XORG!+CONTSHIFTX!
  YMAG(I)=YORG!+CONTSHIFTY!  'YMAG!: SHIFTED
NEXT I

===== GET THE CAL POINT =====
IF CALPTNUM > 0 THEN
  ' CALL MLCCALPT
END IF

END SUB

*
* SUBROUTINE:
*   GETIFLD2 ()
*
* SYNOPSIS:
*   INCLUDE comrecs.inc
*   INCLUDE comir.inc
*   INCLUDE comr3.inc
*
SUB GETIFLD2 STATIC
4400
*
* DESCRIPTION:
*   This subroutine gets irregular field data from the file.
*
* ASSUMPTIONS:
*   This subroutine assumes valid input variables.
*
* GLOBAL VARIABLES:
*   CALPTNUM      O Number of calculation points
*   COLCENTER(I)  O X - Y coordinate of collimator center (cm)
*   COLLEN!       O Collimator length (cm)
*   COLWID!       O Collimator width (cm)
*   DATADIR$      I Directory pointer to a specific patient
*   DATADRV$      I Drive pointer to patient data storage
*   DATAPATH$     I Path pointer to patient data storage
*   DEPTH(I)      O Isoline depths
*   DRV$          O Name of the drive where FILES can be found
*   EDGECODE(I)   O Edge code
*   ERRFLAG       I Status of the file I/O routine
*   FILES         O Temporary pointer to all library filenames
*   FLDEDGE0      O Irregular field outline coordinates (cm * 100)
*   FLDPNTNUM     O Number of vertices in field outlines
*   IFLDNUM       I Current irregular field number
*   IRCALPTO      O X-Y coord. of collimator points (temp array)
*   MAG!          O Field magnification factor
*   PATH$         O Name of the path where FILES can be found
*   PORTDES$      O Port designation label
*   SITE$(I)      O Calc point label
*   SPDI(I)       O Source to point distance for each calc point
*   SSD(I)        O Source to skin distance for each calc point
*   SSDSAD!       O SSD/SAD distance (cm)
*   SSDSADMODE    O 0 = SSD beam, 1 = SAD beam
*   TRAYFAC!      O Tray factor

```

```

* TRTUNTNUM      O Treatment unit file pointer
* WDGANG         O Wedge angle (degrees)
*
* FILES_USED:
*
*
* SUBROUTINES_CALLED:
*   None
*
* AUTHOR:
*   Siyong Kim
*
* REVISION_HISTORY:
*
* =====
*
  ERRFLAG = 0
  IS = MID$(STR$(IFLDNUM), 2, LEN(STR$(IFLDNUM)))
  IF LEN(IS) < 2 THEN
    IS = "0" + IS
  END IF
  DRV$ = DATADRV$
  PATH$ = DATAPATH$
  FILES = DATADIRS + "\IFLD" + IS + ".DAT"

  IF ( OpenFile( DRV$, Path$, File$, INPUTMODE$, 3 ) <> SUCCESS ) THEN
    CALL ERR.Warning( "File Access", "Image:GetIFld", _
      "Cannot open " + DRV$ + Path$ + File$ )
    ERRFLAG = -99
    EXIT SUB
  END IF

  INPUT #3, PORTDESS
  INPUT #3, SSDSADMODE, TRTUNTNUM, CDLWID, COLLEN, WDGANG, TRAYFAC, COLCENTER(10),
  COLCENTER(1)
  INPUT #3, MAG, SSDSAD, FLDPTNUM

  I = FLDPTNUM
  IF I > 0 THEN
    REDIM FLDEGE(0 TO 1, 0 TO 1), EDGECD(0 TO 1)
    IF FLDPTNUM > 0 THEN
      FOR I = 0 TO FLDPTNUM
        INPUT #3, FLDEGE(I, 0), FLDEGE(I, 1), EDGECD(I)
      NEXT I
    END IF
  END IF

  INPUT #3, CALPTNUM
  I = CALPTNUM + 1
  REDIM IRCALPT(1 TO I, 0 TO 1), DEPTH(1 TO I), SSD(1 TO I)
  REDIM SPD(1 TO I), SITES(1 TO I)
  IF CALPTNUM > 0 THEN
    FOR I = 1 TO CALPTNUM
      INPUT #3, SITES(I)
      INPUT #3, IRCALPT(I, 0), IRCALPT(I, 1), DEPTH(I), SSD(I)
      SPD(I) = SSD(I) + DEPTH(I)
    NEXT I
  END IF
  CloseFile 3
END SUB

* =====
*
* SUBROUTINE:
*   SAVEIFLD2 ()
*
*
* SYNOPSIS:
*   INCLUDE comacc.inc
*   INCLUDE comir.inc
*   INCLUDE comac3.inc

```

```

SUB SAVEFLD2 STATIC
4500

```

```

* DESCRIPTION:

```

```

  This subroutine prompts the user to save irregular field data. If the
  user chooses to save the data the Irreg data file and the Irreg
  library file is updated.

```

```

* ASSUMPTIONS:

```

```

  This subroutine assumes valid input variables.

```

```

* GLOBAL_VARIABLES:

```

```

  BEAMTYPE      I 0=photon; 1=Co-60; 2=electron
  CALPTNUM      I Number of calculation points
  COLCENTER(I)  I X - Y coordinate of collimator center (cm)
  COLLEN(I)     I Collimator length (cm)
  COLWID(I)     I Collimator width (cm)
  DATADIR$      I Directory pointer to a specific patient
  DATADRV$      I Drive pointer to patient data storage
  DATAPATH$     I Path pointer to patient data storage
  DEPTH(I)      I Isoline depths
  DRV$          O Name of the drive where FILES can be found
  EDGECODE(I)   I Edge code
  ENERGY       I Nominal energy (Mev)
  ERRFLAG       O Status of the file I/O routine
  FIELDS        M Number of irregular fields stored
  FILES         O Temporary pointer to all library filenames
  FLDEG(I)      I Irregular field outline coordinates (cm * 100)
  FLDPTNUM      I Number of vertices in field outlines
  IFLDNUM       O Current irregular field number
  IRCALPT(I)    I X-Y coord. of collimator points (temp array)
  MAG(I)        I Field magnification factor
  MFLAG(I)      I MLC field exists (0=no, 1=yes)
  PATH$         O Name of the path where FILES can be found
  PORTDESS     I Port designation label
  SITES(I)      I Calc point label
  SSD(I)        I Source to skin distance for each calc point
  SSDSAD(I)     I SSD/SAD distance (cm)
  SSDSADMODE    I 0 = SSD beam, 1 = SAD beam
  TRAYFAC(I)    I Tray factor
  TRTUNT$      I Treatment unit
  TRTUNTNUM     I Treatment unit file pointer
  WDGANG        I Wedge angle (degrees)
  WDGORN        I Wedge orientation

```

```

* FILES_USED:

```

```

  C D: DATAPATH$ \ DATADIR$ \ IFLD##.DAT Irregular field shape coord.

```

```

* SUBROUTINES_CALLED:

```

```

* AUTHOR:

```

```

  Siyong Kim

```

```

* REVISION_HISTORY:

```

```

=====
ERRFLAG = 0
IFLDNUM = FIELDS + 1

CALL DisplayBusyMessage( "Saving opposed field data ...." )

IS = MID$(STR$(IFLDNUM), 2, LEN$(STR$(IFLDNUM)))
IF LEN$(IS) < 2 THEN
  IS = "0" + IS
END IF
DRV$ = DATADRV$
PATH$ = DATAPATH$ + DATADIR$
===== BLOCK FIELD DATA FILE =====

```

```

FILES = "WFLD" + IS + ".DAT"

IF (OpenFile(DRV$, PATH$, FILES, OUTPUTMODE$, 3) <> SUCCESS) THEN
  CALL ERR.Warning("File Access", "Irreg::SaveFld",
    "Cannot write " + Drv$ + Path$ + File$)
  ERRFLAG = -99
  EXIT SUB
END IF

PRINT #3, USING "%", V, PORTDES$
PRINT #3, USING "#####"; SSDSADMODE; TRTUNTNM; COLWID; COLLEN;
WDGANG, TRAYFAC; -COLCENTER(0); COLCENTER(1)
PRINT #3, USING "#####"; MAG; SSDSAD; FLDPTNUM
IF FLDPTNUM > 0 THEN
  FOR I = 0 TO FLDPTNUM
    PRINT #3, USING "#####"; FLDEGE(I, 0); FLDEGE(I, 1); EDGECODE(I)
  NEXT I
END IF
PRINT #3, USING "#####"; CALPTNUM
FOR I = 1 TO CALPTNUM
  PRINT #3, USING "%", V, SITE$(I)
  PRINT #3, USING "#####"; IRCALPT(I, 0); IRCALPT(I, 1); DEPTH(I); SSD(I)
NEXT I
CloseFile 3
' ===== UPDATE IRREGULAR FIELD LIBRARY =====

DRV$ = DATA DRV$
PATH$ = DATA PATH$ + DATA DIR$
FILES = "WREGFLD.LIB"

IF (OpenFile(DRV$, PATH$, FILES, RANDOMMODE$, 4) <> SUCCESS) THEN
  CALL ERR.Warning("File Access", "Irreg::SaveFld",
    "Cannot open " + Drv$ + Path$ + File$)
  ERRFLAG = -99
  EXIT SUB
END IF

FIELD #4, 15 AS PDS, 4 AS TUS, 2 AS EYS, 2 AS BTS, 2 AS CWS,
2 AS CLS, 2 AS SSS, 2 AS SMS, 2 AS WAS, 2 AS WOS,
2 AS CPS, 10 AS EDS, 2 AS NUS,
1 AS MFS, 2 AS MCWS, 2 AS MCLS, 10 AS MEDS,
2 AS MCPS

LSET PDS = PORTDES$
LSET TUS = TRTUNTNM
LSET EYS = MKIS(ENERGY)
LSET BTS = MKIS(BEAMTYPE)
LSET CWS = MKIS(CINT(COLWID * 10))
LSET CLS = MKIS(CINT(COLLEN * 10))
LSET SSS = MKIS(CINT(SSDSAD * 10))
LSET SMS = MKIS(SSDSADMODE)
LSET WOS = MKIS(WDGANG)
LSET WAS = MKIS(WDGANG)
LSET CPS = MKIS(CALPTNUM)
LSET NUS = MKIS(TRTUNTNM)
LSET EDS = DATES
LSET MFS = MFLAG$ 'REV
LSET MCWS = ""
LSET MCLS = ""
LSET MEDS = ""
LSET MCPS = ""
PUT #4, IFLDNUM
IF IFLDNUM = FIELDS + 1 THEN
  FIELDS = FIELDS + 1
  LSET PDS = "-99"
  PUT #4, FIELDS + 1
END IF
CloseFile 4
END SUB

```

```

SUBROUTINE:
  GETMFLD2 ()

SYNOPSIS:
  INCLUDE comrocl.inc
  INCLUDE comar.inc
  INCLUDE comir3.inc

SUB GETMFLD2 STATIC
4600
*
* DESCRIPTION:
*   This subroutine gets MLC field data from the file
*
* ASSUMPTIONS:
*   This subroutine assumes valid input variables.
*
* GLOBAL_VARIABLES:
*   CALPTNUM      I Number of calculation points
*   COLLANGO!     I Collimator angle in degree
*   COLCENTER(I)  I X - Y coordinate of collimator center (cm)
*   COLLEN!       I Collimator length (cm)
*   COLWID!       I Collimator width (cm)
*   DATADIR$      I Directory pointer to a specific patient
*   DATADRV$      I Drive pointer to patient data storage
*   DATAPATH$     I Path pointer to patient data storage
*   DEPTH(I)      I Isoline depths
*   DRV$          O Name of the drive where FILES can be found
*   EDGECODE(I)   I Edge code
*   ERRFLAG       O Status of the file I/O routine
*   FLDEGE(I)     I Irregular field outline coordinates (cm * 100)
*   FLDPNTNUM     I Number of vertices in field outlines
*   IFLDFLAG      O Field loaded? (0=no, 1=yes)
*   IPLDNUM       O Current irregular field number
*   IRCALPT(I)    I X-Y coord. of collimator points (temp array)
*   LEAFNUM       O Number of leaves in one side (26 for Varian, 40 for Philips)
*   LEAFAO(I)     I Leaf position for A side
*   LEAFBO(I)     I Leaf position for B side
*   MLCMAGO!      O Mag. for projection of MLC from 100cm to surface
*   MLCOFFSETXO!  I MLC offset in X-dir. (cm)
*   MLCOFFSETYO!  I MLC offset in Y-dir. (cm)
*   PATH$         O Name of the path where FILES can be found
*   PORTDES$      I Port designation label
*   SITE(I)       I Calc point label
*   SPD(I)        I Source to point distance for each calc point
*   SSD(I)        I Source to skin distance for each calc point

FILES_USED:
*   C D: DATAPATH$DATADIR$ MFLD## DAT   MLC field shape coord

SUBROUTINES_CALLED:

AUTHOR:
  Siyong Kim

REVISION_HISTORY:

[=====]
*
  ERRFLAG = 0
  IS = MID$(STR$(IPLDNUM), 2, LEN$(STR$(IPLDNUM)))
  IF LEN(IS) < 2 THEN
    IS = "0" + IS
  END IF
  DRV$ = DATADRV$
  PATH$ = DATAPATH$
  MFILES = DATADIR$ + "MFLD" + IS + ".DAT"

  IF ( OpenFile(Drv$, Path$, MFILES, INPUTMODES, 3) <> SUCCESS ) THEN
    CALL ERR.Warning( "File Access", "Irreg:GetMFLd" ) _

```

```

      "Cannot open " + Drv$ + Path$ + File$ )
    ERRFLAG = -99
  EXIT SUB
END IF

INPUT #3, PORTDESS
INPUT #3, COLWID!, COLLEN!, COLCENTER!(0), COLCENTER!(1), COLLANGO!, MLCOFFSETX!, MLCOFFSETY!,
MLCMAGO!
INPUT #3, LEAFNUM

FOR I = 0 TO LEAFNUM-1
  INPUT #3, LEAFAO!(I), LEAFBO!(I)
NEXT I

INPUT #3, FLDPTNUM
I = FLDPTNUM
IF I > 0 THEN
  REDIM FLDEGE(0 TO I, 0 TO 1), EDGECD(0 TO I)
  IF FLDPTNUM > 0 THEN
    FOR I = 0 TO FLDPTNUM
      INPUT #3, FLDEGE(I, 0), FLDEGE(I, 1), EDGECD(I)
    NEXT I
    FLDXFLAG = 1
  END IF
END IF

INPUT #3, CALPTNUM
I = CALPTNUM + 1
REDIM IRCALPT(1 TO I, 0 TO 1), DEPTH!(1 TO I), SSD!(1 TO I)
REDIM SPD!(1 TO I), SITE$(1 TO I)
IF CALPTNUM > 0 THEN
  FOR I = 1 TO CALPTNUM
    INPUT #3, SITE$(I)
    INPUT #3, IRCALPT(I, 0), IRCALPT(I, 1), DEPTH!(I), SSD!(I)
    SPD!(I) = SSD!(I) + DEPTH!(I)
  NEXT I
END IF
CloseFile 3
END SUB

'=====
'
' SUBROUTINE:
'   SAVEMFLD2 ()
'
' SYNOPSIS:
'   INCLUDE comrcc.inc
'   INCLUDE comir.inc
'   INCLUDE comir3.inc
'
SUB SAVEMFLD2 STATIC
4700
'
' DESCRIPTION:
'   This subroutine prompts the user to save MLC field data. If the
'   user chooses to save the data the MLC data file and the lrrcg
'   library file is updated.
'
' ASSUMPTIONS:
'   This subroutine assumes valid input variables.
'
' GLOBAL VARIABLES:
'   AXDATA(X)  1 X-coordinate data of leaf A
'   BEAMTYPE    1=photon, 1=Co-60; 2=electron
'   BXDATA(X)   1 X-coordinate data of leaf B
'   CALPTNUM    1 Number of calculation points
'   COLLANG!    1 Collimator angle in degree
'   COLCENTER!(0) 1 X - Y coordinate of collimator center (cm)
'   COLLEN!     1 Collimator length (cm)
'   COLWID!     1 Collimator width (cm)
'   CONTSHTFX!  1 MLC offset in X-dir. (cm)

```

```

CONTSHTY! 1 MLC offset in Y-dir. (cm)
* DATADIR$ 1 Directory pointer to a specific patient
* DATADRV$ 1 Drive pointer to patient data storage
* DATAPATH$ 1 Path pointer to patient data storage
* DEPTH() 1 Isoline depths
* DRV$ D Name of the drive where FILES can be found
* EDGECODE() 1 Edge code
* EDITMDDE 1 Beam calculation status flag
* ENERGY 1 Nominal energy (Mev)
* ERRFLAG 0 Status of the file I/O routine
* FIELDS M Number of irregular fields stored
* FILE$ 0 Temporary pointer to all library filenames
* FLDEGE() 1 Irregular field outline coordinates (cm * 100)
* FLDPTNUM 1 Number of vertices in field outlines
* IFLDNUM D Current irregular field number
* IRCALPT() 1 X-Y coord. of collimator points (temp array)
* IMLCSAVE 1 Save MLC field or not (0=no, 1=yes),
for 0, only collimator center is calculated
* LEAFNUM 0 Number of leaves in one side (26 for Varian, 40 for Philips)
* MAG! 1 Field magnification factor
* MFLAG$ 1 MLC field exists (N=no, V=Varian, P=Philips)
* MLCFLAG 1 MLC field editor is on (0=no, 1=yes)
* MLCMAG! 0 Mag. for projection of MLC from 100cm to surface
* MLCTYPE D Type of MLC (1 = Varian, 2 = Philips)
* ROW 1 Index for first row in menu box
* PATH$ D Name of the path where FILES can be found
* PORTDESS 1 Port designation label
* RDW 1 Index for first row in menu box
* SITE() 1 Calc point label
* SSD() 1 Source to skin distance for each calc point
* SSDSAD! 1 SSD/SAD distance (cm)
* SSDSADMODE 1 0 = SSD beam, 1 = SAD beam
* TRAYFAC! 1 Tray factor
* TRTUNT$ 1 Treatment unit
* TRTUNTNUM 1 Treatment unit file pointer
* WDGANG 1 Wedge angle (degrees)
* WDGORN 1 Wedge orientation

```

FILES_USED:

```

C D: DATAPATH$DATADIR$ IFLD#.DAT Irregular field shape coord.
C D: DATAPATH$DATADIR$ MFLD#.DAT MLC field shape coord.

```

SUBROUTINES_CALLED:

```

KYB.GetString$ Retrieves a string of MaxLen length. Handles
specified keys with ASCII code 32-126. Also,
could return RET or ESC string.
MENUCLR Clear menu/command area & display time/version
& title
MFLDDATA Gets collimator opening, field outline and
calculation point location for MLC field
GETIRLD2 Gets irregular field data from the file

```

AUTHDR:

```

Siyong Kim

```

REVISION_HISTORY

```

=====
ERRFLAG = 0
IFLDNUM = FIELDS + 1

CALL DisplayBusyMessage( "Saving MLC field data ..." )

IS = MID$(STR$(IFLDNUM), 2, LEN$(STR$(IFLDNUM)))
IF LEN$(IS) < 2 THEN
    IS = "0" + IS
END IF
DRV$ = DATADRV$
PATH$ = DATAPATH$ + DATADIR$

```

```
MFILES = "MFLD" + IS + ".DAT"
```

```
IF ( OpenFile( DRVS, PATHS, MFILES, OUTPUTMODES, 3 ) <> SUCCESS ) THEN
```

```
  CALL ERR.Warning( "File Access", "Irreg::SaveMFlD", _  
    "Cannot write " + Drv$ + Path$ + File$ )
```

```
  ERRFLAG = -99
```

```
  EXIT SUB
```

```
END IF
```

```
PRINT #3, USING "      V"; PORTDESS
```

```
PRINT #3, USING "##### +### ## +### ## +### ## +### ## +### ## +### ## +### ##"; COLWID!, COLLEN!, -COLCENTER!(0),  
COLCENTER!(1), -COLLANGO!, -MLCOFFSETXO!, MLCOFFSETYO!, MLCMAGO!
```

```
PRINT #3, USING "###"; LEAFNUM
```

```
FOR I = 0 TO LEAFNUM-1
```

```
  PRINT #3, USING "+### ## +### ##"; -LEAFBO(I), -LEAFAO(I)
```

```
  NEXT I
```

```
PRINT #3, USING "###"; FLDPNTNUM
```

```
IF FLDPNTNUM > 0 THEN
```

```
  FOR I = 0 TO FLDPNTNUM
```

```
    EDGECODE(I) = 1
```

```
    PRINT #3, USING "+#### +#### #"; -FLDEDGE(I, 0), FLDEDGE(I, 1), EDGECODE(I)
```

```
  NEXT I
```

```
END IF
```

```
PRINT #3, USING "###"; CALPTNUM
```

```
FOR I = 1 TO CALPTNUM
```

```
  PRINT #3, USING "      V"; SITE$(I)
```

```
  PRINT #3, USING "+#### +#### ## ## +#### #"; -IRCALPT(I, 0), IRCALPT(I, 1), DEPTH(I), SSD(I)
```

```
  NEXT I
```

```
CloseFile 3
```

```
' ===== UPDATE IRREGULAR FIELD LIBRARY WITH MLC DATA =====
```

```
MCOLWID! = COLWID!
```

```
MCOLLEN! = COLLEN!
```

```
MCALPTNUM = CALPTNUM
```

```
DRVS = DATADRV$
```

```
PATHS = DATAPATH$ + DATADIR$
```

```
FILES = "IRREGFLD.LIB"
```

```
IF ( OpenFile( DRVS, PATHS, FILES, RANDOMMODE$, 4 ) <> SUCCESS ) THEN
```

```
  CALL ERR.Warning( "File Access", "Irreg::SaveIFld", _  
    "Cannot open " + Dev$ + Path$ + File$ )
```

```
  ERRFLAG = -99
```

```
  EXIT SUB
```

```
END IF
```

```
FIELD #4, 15 AS PD$, 4 AS TUS$, 2 AS EYS$, 2 AS BT$, 2 AS CW$,
```

```
2 AS CL$, 2 AS SSS$, 2 AS SMS$, 2 AS WAS$, 2 AS WOS$,
```

```
2 AS CPS$, 10 AS ED$, 2 AS NUS$,
```

```
1 AS MP$, 2 AS MCW$, 2 AS MCL$, 10 AS MED$,
```

```
2 AS MCP$
```

```
GET #4, IFLDNUM
```

```
COLWID! = CSNG(CV(CW$))*0.1
```

```
COLLEN! = CSNG(CV(CL$))*0.1
```

```
CALPTNUM = CV(CPS$)
```

```
LSET PD$ = PORTDESS
```

```
LSET TUS$ = TRTUNTS
```

```
LSET EYS$ = MKIS(ENERGY)
```

```
LSET BT$ = MKIS(BEAMTYPE)
```

```
LSET CW$ = MKIS(CINT(COLWID! * 10))
```

```
LSET CL$ = MKIS(CINT(COLLEN! * 10))
```

```
LSET SSS$ = MKIS(CINT(SSDSAD! * 10))
```

```
LSET SMS$ = MKIS(SSDSADMODE)
```

```
LSET WOS$ = MKIS(WDGORN)
```

```
LSET WAS$ = MKIS(WDGANG)
```

```
LSET CPS$ = MKIS(CALPTNUM)
```

```
LSET NUS$ = MKIS(TRTUNTNUM)
```

```
LSET ED$ = DATES
```

```

LSET MFS = MFLAGS 'REV
LSET MCWS = MKIS(CINT(MCOLWID! * 10))
LSET MCLS = MKIS(CINT(MCOLLEN! * 10))
LSET MEDS = DATES
LSET MCP5 = MKIS(MCALPTNUM)
PUT #4, IFLDNUM
IF IFLDNUM = FIELDS + 1 THEN
    FIELDS = FIELDS + 1
    LSET FDS = "-99"
    PUT #4, FIELDS + 1
END IF
CloseFile 4

END SUB

=====
'
' SUBROUTINE:
'   MLCOPPOSE ()
'
' SYNOPSIS:
'   INCLUDE comproc.inc
'   INCLUDE comar.inc
'   INCLUDE comir3.inc
'
SUB MLCOPPOSE STATIC
4800
'
' DESCRIPTION
'   This subroutine creates opposed MLC field. Opposed block field is
'   generated at the same time.
'
' ASSUMPTIONS
'   This subroutine assumes valid input variables.
'
' GLOBAL_VARIABLES:
'   BS           O Temporary string
'   CHCS()       O An array of character strings which make up main menu
'   ERRFLAG      O Status of the file I/O routine
'   FIELDS       M Number of irregular fields stored
'   IFLDNUM      O Current irregular field number
'   ROW          I Index for first row in menu box
'   PORTDES$     I Port designation label
'
' FILES_USED:
'
' SUBROUTINES_CALLED:
'   KYB.GetStrExclude$ Retrieves a string of MaxLen length. Enables
'       keys with ASCII code 32-126 except those
'       specified. Also, could return RET or ESC string.
'   MENUCLR      Clear menu/command area & display time/version
'       & title
'   GETIFLD2     Gets irregular field data from the file
'   GETMFLD2     Gets MLC field data from the file
'   SAVEIFLD2    Saves irregular field data
'   SAVEMFLD2    Saves MLC field data
'
' AUTHOR:
'   Syeong Kim
'
' REVISION_HISTORY:
'
'=====
'
'   CHCS(0) = " MLC FIELD EDITOR "
'   CALL MENUCLR
'   LOCATE ROW + 2, 10
'   PRINT "Port label for oppose field (15 Chr).";
'   TXT5 = "<" + OPFPORTDES$ + ">"
'   LOCATE ROW, 3
'   PRINT "ENTER."; TXT5;

```

```

===== User input =====
B$ = K.YB.GetStrExclude$(CHR$(34) + CHR$(44), 15)
SELECT CASE B$

    CASE "ESC"
        EXIT SUB

    CASE "RET"

    CASE ELSE
        OPPORTDESS = B$

END SELECT

===== GET BLOCK FIELD DATA =====

IFLDNUMO = IFLDNUM
FIELD$O = FIELD$

CALL GETIFLD2
IF ERRFLAG = -99 THEN
    ERRFLAG = 0
    EXIT SUB
END IF
===== SAVE OPPOSED BLOCK FIELD =====

PORTDESS = OPPORTDESS
CALL SAVEIFLD2
IF ERRFLAG = -99 THEN
    ERRFLAG = 0
    EXIT SUB
END IF

IFLDNUM = IFLDNUMO
FIELD$ = FIELD$O

===== GET MLC FIELD DATA =====

CALL GETMFLD2
IF ERRFLAG = -99 THEN
    ERRFLAG = 0
    EXIT SUB
END IF

===== SAVE OPPOSED MLC FIELD =====

PORTDESS = OPPORTDESS
CALL SAVEMFLD2

END SUB

* =====
*
* SUBROUTINE:
*   MLCEXPORTV ()
*
* SYNOPSIS:
*   INCLUDE comexs.inc
*   INCLUDE comir.inc
*   INCLUDE comr3.inc
*
SUB MLCEXPORTV STATIC
4900
*
* DESCRIPTION:
*   This subroutine creates exported MLC field data file for varian type
*   Exported file can be directly used by varian MLC software "SHAPEP".
*
* ASSUMPTIONS:

```

```

' This subroutine assumes valid input variables
'
GLOBAL_VARIABLES:
' BS O Temporary string
' COLLANGO! I Collimator angle in degree
' ERRFLAG O Status of the file I/O routine
' FIELDS M Number of irregular fields stored
' FLDEGDE! I Irregular field outline coordinates (cm * 100)
' FLDPNTNUM I Number of vertices in field outlines
' LEAFAO! I Leaf position for A side
' LEAFBO! I Leaf position for B side
' LEAFNUM O Number of leaves in one side (26 for Varian, 40 for Philips)
' MFLAGS I MLC field exists (N=No, V=Varian, P=Philips)
' MLCMAG! O Mag. for projection of MLC from 100cm to surface
' MLCOFFSETXO! I MLC offset in X-dir. (cm)
' MLCOFFSETYO! I MLC offset in Y-dir. (cm)
' PATNUMBS O Patient Number
' PORTLESS I Port designation label
' ROW I Index for first row in menu box
'
FILES_USED:
'
SUBROUTINES_CALLED:
' ERR.menusc Display error message on line 5 of menu area
' GETDRVPATH Get export drive and path designations
' GETIFLD2 Gets irregular field data from the file
' GETMFLD2 Gets MLC field data from the file
' KYB.GetInt$ Get keyboard input in integer format
' KYB.GetString$ Removes a string of MaxLen length. Enables
' specified keys with ASCII code 32-126. Also,
' could return RET or ESC string
' KYB.GetString$ Removes a string of MaxLen length. Enables
' keys with ASCII code 32-126 except those
' specified. Also, could return RET or ESC string.
' KYB.PAGEKeysOFF Disable PGUP and PGDN keys
' KYB.PAGEKeysON Enable the paging keys (PGUP, PGDN).
' MENUCLR Clear menu/command area & display time/version
' & title
' PAGEDN Keeps track of page information and file pointer
' information and displays the next page
' if there is one
' PAGEUP Keeps track of page information and file pointer
' information and displays the previous page
' if there is one
'
AUTHOR:
' Syong Kim
'
REVISION_HISTORY
'
'=====
'
DIM EXPNUM(1 TO FIELDS), FIELDNAMES(1 TO FIELDS)
LEAFNUM = 26

'===== Define a header structure for VARIAN MLC =====
FileRev$ = "File Rev = "
LastName$ = "Last Name = "
FirstName$ = "First Name = "
PatientID$ = "Patient ID = "
NumberOfFields$ = "Number of Fields = "

Field$ = "Field = "
TreatmentCount$ = "Treatment Count = "
Operator$ = "Operator = "
Collimator$ = "Collimator = "
Gantry$ = "Gantry = "
Leaf$ = "Leaf = "

Note$ = "Note = "

```

```

Shape$ = "Shape ="
Magnification$ = "Magnification ="

DFileRev$ = "C"
' ===== GET EXPORT DRIVE AND PATH =====
GETPATH:
CALL GETDRVPATH
IF ERRFLAG = -99 THEN
    ERRFLAG = 0
    ERASE EXPNUM, FIELDNAMES
    EXIT SUB
END IF

' ===== GET EXPORT FILE NAME =====
GETFILE:
CALL MENUCLR
LOCATE ROW + 2, 10
PRINT "Enter export file name (8 Chr).";
EXPPFILES = ""
FILETXT$ = "<" + EXPPFILES + ">"
LOCATE ROW, 3
PRINT "ENTER-"; FILETXT$;

' ===== User input =====
B$ = KYB.GetStrExclude$(CHR$(34) + CHR$(44) + CHR$(46), 8)
SELECT CASE B$

    CASE "ESC"
        GOTO GETPATH

    CASE "RET"
        OS.Sound 261, 2
        GOTO GETFILE

    CASE ELSE
        EXPPFILES = B$

END SELECT

' ===== CREATE EXPORT FILE NAME =====
EXPPFILES = "<" + EXPPFILES + ".MLC"

' ===== OPEN EXPORT FILE =====
CHKRET:
CALL DisplayBusyMessage( "Open export file..." )

IF ( OpenFile( EXPDRV$, EXPPATH$, EXPPFILES, OUTPUTMODE$, 2 ) <> SUCCESS ) THEN
    CALL ERR.Warning( "File Access", "Ineg:MLCexpo"...
        "Cannot open " + EXPDRV$ + EXPPATH$ + EXPPFILES )
    GOTO GETPATH
END IF

' ===== GET PATIENT FIRST NAME =====
FNAME
CALL MENUCLR
LOCATE ROW + 2, 10
PRINT "Enter patient first name (15 Chr). ";
DFirstName$ = ""
FSTNAMETXT$ = "<" + DFirstName$ + ">"
LOCATE ROW, 3
PRINT "ENTER-"; FSTNAMETXT$;

' ===== User input =====
B$ = KYB.GetStrExclude$(CHR$(34) + CHR$(44), 15)
SELECT CASE B$

    CASE "ESC"
        CloseFile 2
        GOTO GETFILE

    CASE "RET"

```

```

OS.Sound 261, 2
GOTO FNAME

CASE ELSE
  DFirstName$ = B$

END SELECT

'===== GET PATIENT LAST NAME =====
LNAME:
CALL MENUCLR
LOCATE ROW + 2, 10
PRINT "Enter patient last name (15 Chr) .:"
DLastName$ = ""
LNAME$ = "<" + DLastName$ + ">"
LOCATE ROW, 3
PRINT "ENTER.:", LNAME$;

'===== User input =====
B$ = KYB.GetString$(CHR$(34) + CHR$(44), 15)
SELECT CASE B$

CASE "ESC"
  GOTO FNAME

CASE "RET"
  OS.Sound 261, 2
  GOTO LNAME

CASE ELSE
  DLastName$ = B$

END SELECT

'===== GET PATIENT ID =====
PTID:
CALL MENUCLR
LOCATE ROW + 2, 10
PRINT "Enter patient ID.:"
DPatientID$ = PATNUMB$
IDT$ = "<" + DPatientID$ + ">"
LOCATE ROW, 3
PRINT "ENTER.:", IDT$;

'===== User input =====
B$ = KYB.GetString$(CHR$(34) + CHR$(44), 15)
SELECT CASE B$

CASE "ESC"
  GOTO LNAME

CASE "RET"
  OS.Sound 261, 2
  GOTO PTID

CASE ELSE
  DPatientID$ = B$

END SELECT

'===== CHECK TOTAL NUMBER OF MLC FIELDS =====
FIELD #4, 15 AS PD$, 4 AS TUS, 2 AS EYS, 2 AS BTS, 2 AS CWS,
2 AS CLS, 2 AS SSS, 2 AS SMS, 2 AS WAS, 2 AS WOS,
2 AS CPS, 10 AS EDS, 2 AS NUS,
1 AS MPS, 2 AS MCWS, 2 AS MCLS, 10 AS MEDS,
2 AS MCP$

VMLCFLDS = 0
PMLCFLDS = 0
FOR I = 1 TO FIELDS

```

```

      GET #4, I
      MFLAG$ = MFS
      IF MFLAG$ = "V" THEN
        VMLCFLDS = VMLCFLDS + 1
      END IF
    NEXT I
    TOTMLCFLDS = VMLCFLDS

' ===== GET NUMBER OF FIELDS TO BE EXPORTED =====
NOFLDS:
DO
  CALL MENUCLR
  LOCATE ROW + 2, 10
  PRINT "How many fields to be exported?";
  LOCATE ROW + 3, 10
  PRINT "Enter # of fields";

  IF FIELDS > 15 THEN
    LOCATE ROW + 3, 59
    PRINT "PgUp PgDn";
    CALL KYB.PAGEKeysON
  END IF
TOTFLD0:
  LOCATE ROW, 3
  PRINT USING "ENTER: <##>:", TOTMLCFLDS;
  B$ = KYB.GetInt$(10,2)
  CALL KYB.PAGEKeysOFF

  SELECT CASE B$

    CASE "PGUP"
      CALL PAGEUP

    CASE "PGDN"
      CALL PAGEDN

    CASE "ESC"
      GOTO PTID

    CASE "RET"
      DNumberOfFields = TOTMLCFLDS
      GOTO TOTFLD1

    CASE ELSE
      DNumberOfFields = VAL(B$)

TOTFLD1:
  IF DNumberOfFields < 1 OR DNumberOfFields > TOTMLCFLDS THEN
    CALL ERR.menu$( "INVALID NUMBER OF FIELDS - RE-ENTER", "", "" )
    GOTO TOTFLD0
  END IF
  EXIT DO
END SELECT
LOOP

' ===== SELECT FIELDS TO BE EXPORTED =====
OLDIFLDNUM = IFLDNUM
EXFLDNUM = 0
FOR I = 1 TO DNumberOfFields
DO
EXFLDM:
  CALL MENUCLR
  LOCATE ROW + 2, 10
  IF I = 1 THEN
    PRINT "Enter Field # for 1st Field to be exported.";
  ELSEIF I = 2 THEN
    PRINT "Enter Field # for 2nd Field to be exported.";
  ELSEIF I = 3 THEN
    PRINT "Enter Field # for 3rd Field to be exported.";
  
```

```

ELSE
    PRINT "Enter Field # for "; I, "th Field to be exported.";
END IF
LOCATE ROW + 3, 10
PRINT "Last Field # selected : ", EXFLDNUM;

IF FIELDS > 15 THEN
    LOCATE ROW + 3, 59
    PRINT "PgUp PgDn";
    CALL KYB.PAGEKeysON
END IF
EXFLDNUM = EXFLDNUM + 1

EXFLD0:
    LOCATE ROW, 3
    PRINT USING "ENTER: <##>"; EXFLDNUM;
    B5 = KYB.GetInt$(10,2)
    CALL KYB.PAGEKeysOFF

    SELECT CASE B5

        CASE "PGUP"
            CALL PAGEUP

        CASE "PGDN"
            CALL PAGEDN

        CASE "ESC"

            IF I = 1 THEN
                GOTO NOFLDS
            ELSE
                I = I - 1
                IM = I - 1
                IF IM = 0 THEN
                    EXFLDNUM = 0
                ELSE
                    EXFLDNUM = EXPNUM(I-1)
                END IF
                GOTO EXFLDM
            END IF

        CASE "RET"
            GOTO EXFLDI

        CASE ELSE

            EXFLDNUM = VAL(B5)

EXFLD1:
            IF EXFLDNUM < 1 OR EXFLDNUM > FIELDS THEN
                CALL ERR.menu5c("INVALID FIELD NUMBER - RE-ENTER", "", "")
                GOTO EXFLD0
            END IF

            GET #4, EXFLDNUM
            MFLAG5 = MFS
            IF MFLAG5 = "P" THEN
                CALL ERR.menu5c("MLC TYPE MISMATCH - RE-ENTER", "", "")
                GOTO EXFLD0
            ELSEIF MFLAG5 = "N" THEN
                CALL ERR.menu5c("NO MLC FIELD - RE-ENTER", "", "")
                GOTO EXFLD0
            ELSE
                END IF
            EXIT DO

    END SELECT
LOOP

EXPNUM(I) = EXFLDNUM

```

```

NEXT I

'===== WRITING EXPORT DATA ON EXPORT FILE =====

'===== PRINT HEADER =====
CALL DisplayBusyMessage( "Writing file header..." )

PRINT #2, FileRev$, LTRIM$(DFileRev$)
PRINT #2, LastName$, LTRIM$(DLastName$)
PRINT #2, FirstName$, LTRIM$(DFirstName$)
PRINT #2, PatientID$, LTRIM$(DPatientID$)
PRINT #2, Number of Fields$, DNumberOffields
BLK$ = ""
PRINT #2, BLK$

'===== FOR EACH FIELD =====
FOR K = 1 TO DNumberOffields
  CALL DisplayBusyMessage( "Writing field data.." )

  IFLDNUM = EXPNUM(K)
  CALL GETMFLD2
  PORTDESS = UCASE$(PORTDESS)
  DEMAG! = 1/MLCMAGO!
  '===== CHECK FIELD NAME =====

  IF K > 1 THEN
CHKFLD:
    FOR ICK = 1 TO K-1
      IF PORTDESS = FIELDNAMES(ICK) THEN
        '===== GET NEW FIELD NAME =====
        CALL MENUCLR
        LOCATE ROW + 2, 10
        PRINT "Duplicated PORT Label...";
        LOCATE ROW + 3, 10
        PRINT "Enter New PORT Label for Field # "; IFLDNUM, " (15 Chars)";
        LOCATE ROW, 3
        PRINT "ENTER.:"; "<";
CHKFLD1:
        '===== User input =====
        B$ = KVB.GetStrExclude$(CHR$(34) + CHR$(44), 15)
        SELECT CASE B$

          CASE "RET", "ESE"
            OS Sound 261, 2
            GOTO CHKFLD1

          CASE ELSE
            PORTDESS = UCASE$(B$)

        END SELECT
        GOTO CHKFLD
      END IF
    NEXT ICK
    CALL DisplayBusyMessage( "Writing field data.." )
  END IF
  FIELDNAMES(K) = PORTDESS

  '===== PRINT FIELD HEADER =====
  PRINT #2, Field$, LTRIM$(PORTDESS)
  PRINT #2, TreatmentCount$, DTreatmentCount
  PRINT #2, Operator$, LTRIM$(DOperator$)
  PRINT #2, Collimator$, COLLANGO!
  PRINT #2, Gantry$, DGantry!
  '===== PRINT LEAF POSITION =====
  FOR ILEAF = 1 TO LEAFNUM
    I$ = MID$(STR$(ILEAF), 2, LEN(STR$(ILEAF)))
    IF LEN(I$) < 2 THEN
      I$ = " " + I$
    END IF
    LEAFAS = LEAF$ + I$ + "A ="
  
```

```

        PRINT #2, LEAF$5, LEAF$10(I)
    NEXT ILEAF
    FOR ILEAF = 1 TO LEAFNUM
        IS = MID$(STR$(ILEAF), 2, LEN(STR$(ILEAF)))
        IF LEN(IS) < 2 THEN
            IS = " " + IS
        END IF

        LEAFB$ = LEAF$ + IS + "B = "
        PRINT #2, LEAFB$, -LEAFBO(I)
    NEXT ILEAF

    PRINT #2, Note$, 0
    CALL GETIFLO2
    PRINT #2, Shape$, FLOPTNUM+1
    FOR IPT = 0 TO FLOPTNUM
        XIPT1 = (FLDEGE(IPT, 0)*0.01 + MLCOFFSETXO)*OEMAG!
        XIPT1 = (FLDEGE(IPT, 0)*0.01 + MLCOFFSETXO)
        FLDEGE(IPT, 0) = CINT(XIPT1*100!)
        YIPT1 = (FLOEDGE(IPT, 1)*0.01 + MLCOFFSETO)*OEMAG!
        YIPT1 = (FLOEDGE(IPT, 1)*0.01 + MLCOFFSETO)
        FLOEDGE(IPT, 1) = CINT(YIPT1*100!)

        PRINT #2, FLOEDGE(IPT, 0), FLOEDGE(IPT, 1)
    NEXT IPT
    PRINT #2, Magnification$, MLCMAGO!
    PRINT #2, ""
NEXT K

CloseFile 2
IFLONUM = OLOFLONUM

CALL DisplayErrorMessage("Export file successfully created...")
CALL MENUCLR
LOCATE ROW + 1, 10
PRINT "Export file "; EXPFILES; "\ successfully created ";
LOCATE ROW + 3, 12
PRINT "Press any key to continue ...";
OO
LOOP WHILE INKEY$ = ""

ERASE EXPNUM, FIELONAMES
END SUB

'=====
' SUBROUTINE:
'   MLCSELECT ()
'
' SYNOPSIS:
'   INCLUDE comproc.inc
'   INCLUDE comir.inc
'   INCLUDE comu3.inc
'
SUB MLCSELECT STATIC
5000
'
' DESCRIPTION:
'   This subroutine prompts the user to select MLC type
'
' ASSUMPTIONS:
'   This subroutine assumes valid input variables.
'
' GLOBAL VARIABLES:
'   CHCS()      O An array of character strings which make up main menu
'   ERRFLAG     O Status of the file I/O routine
'   MLCTYPE     O Type of MLC (1 = Varus, 2 = Philips)
'   MLCVENDOR$  O String of MLC type
'   ROW         I Index for first row in menu box

```

```

* FILES_USED:
*
* SUBROUTINES_CALLED:
*   KYB.GetStrInclude5 Retrieves a string of MaxLen length Enables
*   specified keys with ASCII code 32-126. Also,
*   could return RET or ESC string
*   MENUCLR          Clear menu/command area & display time/version
*   & title
*
* AUTHOR:
*   Siyong Kim
*
* REVISION_HISTORY:
*
* =====
* {
* !
  ERRFLAG = 0
  ' ===== SET DEFAULT MLC =====

  DEFAULTMLC = 1 'VARIAN

  ' ===== MLC TYPE SELECTION =====

  CHC$(0) = ' MLC FIELD EDITOR '
  CALL MENUCLR
  LOCATE ROW + 1, 10
  PRINT "Select MLC type...";
  LOCATE ROW + 2, 12
  PRINT "V... Varian MLC";
  LOCATE ROW + 3, 12
  PRINT "P... Philips MLC";
  LOCATE ROW, 3
  IF DEFAULTMLC = 1 THEN
    PRINT "ENTER: "; "<","V";">";
  ELSEIF DEFAULTMLC = 2 THEN
    PRINT "ENTER: "; "<","P";">";
  END IF

  ' ===== User input =====
  BB$ = KYB.GetStrInclude5("VvPp", 1)
  SELECT CASE BB$

    CASE "ESC"
      ERRFLAG = -99
      EXIT SUB

    CASE "RET"
      IF DEFAULTMLC = 1 THEN
        MLCTYPE = 1
        MLCVENDOR$ = "VARIAN"
      ELSEIF DEFAULTMLC = 2 THEN
        MLCTYPE = 2
        MLCVENDOR$ = "PHILIPS"
      END IF
      EXIT SUB

    CASE ELSE
      IF BB$ = "V" OR BB$ = "v" THEN
        MLCTYPE = 1
        MLCVENDOR$ = "VARIAN"
        EXIT SUB
      ELSEIF BB$ = "P" OR BB$ = "p" THEN
        MLCTYPE = 2
        MLCVENDOR$ = "PHILIPS"
        EXIT SUB
      END IF
    END SELECT

  END SUB

* =====

```

```

SUBROUTINE:
  MLCIPAGE ()

SYNOPSIS:
  INCLUDE comrocs.inc
  INCLUDE comir.inc
  INCLUDE comir3.inc

SUB MLCIPAGE STATIC
5100

DESCRIPTION:
  This subroutine displays one page of beam information for MLC field

ASSUMPTIONS:
  This subroutine assumes the IRREGFLD.LIB is open and contains valid
  values.

GLOBAL_VARIABLES:
  I          O Temporary integer
  IFLDNUM    I Current irregular field number
  ROWCNT     O Temp index to current text row
  TOPOINT    I Pointer to first record on screen

FILES_USED:
  R P: DATAPATHS\DATADIRS\IRREGFLD.LIB Irregular field library

SUBROUTINES_CALLED:
  None

AUTHOR:
  Siyoung Kim

REVISION_HISTORY:

=====
!
  FIELD #4, 15 AS PDS, 4 AS TUS, 2 AS EYS, 2 AS BTS, 2 AS CWS,
    2 AS CLS, 2 AS SSS, 2 AS SMS, 2 AS WAS, 2 AS WOS,
    2 AS CPS, 10 AS EDS, 2 AS NUS,
    1 AS MFS, 2 AS MCWS, 2 AS MCLS, 10 AS MEDS,
    2 AS MCPs

  FOR I = 4 TO 18
    LOCATE I, 1
    PRINT SPACES(80)
  NEXT
  ROWCNT = 4
  POINTER = TOPOINT
  DO
    GET #4, POINTER
    IF CVAL(WOS) = -1 THEN
      SS = "-"
    ELSE
      SS = "+"
    END IF
    IF CVAL(SMS) = 1 THEN
      IS = "I"
    ELSE
      IS = "S"
    END IF
    IF MFS = "V" THEN
      MFSS = " V"
    ELSEIF MFS = "P" THEN
      MFSS = " P"
    ELSE
      MFSS = " No"
    END IF
    LOCATE ROWCNT, 1
    IF MFS = "N" THEN

```


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BIOGRAPHICAL SKETCH

Siyong Kim was born 28 January 1962, in Seoul, the capital of Korea. As the second of two sons of Sungjin Kim and Jungsook Ahn Kim, he grew up in Seoul.

In February, 1980, Siyong graduated from Young-deung-po High School, Seoul, Korea. He attended Seoul National University, Seoul, Korea, starting March, 1980. He graduated from Seoul National University in February, 1984, with a Bachelor of Science in nuclear engineering. After graduation, he started to work as temporary researcher at Korea Advanced Research Institute. He participated in the development of code package for nuclear design in nuclear power plant. At the same time, he attended graduate school at Seoul National University and obtained a Master of Science in nuclear engineering, specialized in neutronics, in February of 1986. He developed a 3-dimensional neutronics code for nuclear design during the study. He served military duty from June, 1986, to September, 1988. In June, 1989, he re-entered Korea Advanced Research Institute as a researcher. He took overseas training for 13 months from November of 1989 to December of 1990 in KWU of SIEMENS, West Germany, to be a responsible nuclear designer. He performed nuclear design for the reload core of 6 and 7 cycles of Kori Nuclear Power Plant Unit 3, Kori, Korea. Promoted to senior researcher in September, 1991, he took the responsibility of quality assurance.

On 3rd of March, 1990, Siyong married the former Gyejin Jang of Seoul, Korea, who he had met first in January of 1986 and had fallen in love with. They have two daughters, Minkyung, born in January of 1991 and Michelle Minna, born in November of 1996.

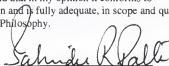
Being tired of the fact that the business of a nuclear power plant was too much affected by political situations, Siyong decided to study medical and health physics and entered the graduate program of medical health physics in the former Department of Nuclear Engineering Science, University of Florida, Gainesville, Florida, in August of 1993. Since August of 1994, he has worked for Dr. Jatinder R. Palta as a research assistant in the Department of Radiation Oncology, University of Florida. He was very pleased to have had the opportunity to work with the people in the physics group of the Department of Radiation Oncology. As a research assistant, he participated in the setup of physics data for both ROCS and ADAC pinnacle treatment planning systems. He also developed an MLC module for ROCS and a generalized algorithm for in-air output factor calculation.

Siyong was awarded the Korean Honor Scholarship in September, 1996. He was also awarded the OISP (Office of International Studies & Programs) award for academic achievement three times, in 1995, 1996, and 1997. He is a member of the Alpha Nu Sigma National Nuclear Science and Engineering Honor Society.

Siyong will receive the degree of Doctor of Philosophy on 9 August 1997. After graduation, he will join the physics group of the Department of Radiation Oncology, University of Florida, as clinical physics resident for 1 year. Then, he will work in the

Department of Radiation Oncology, Ajou University, Suwon, Korea, as assistant professor.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



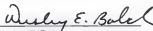
Jatinder R. Palta, Chair
Professor of Nuclear and Radiological
Engineering

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



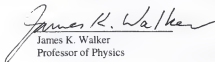
Timothy C. Zhu
Assistant Professor of Nuclear and
Radiological Engineering

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Wesley E. Bolch
Associate Professor of Nuclear and
Radiological Engineering

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James K. Walker
Professor of Physics

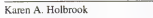
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William Mendenhall
Professor of Radiation Oncology

This dissertation was submitted to the Graduate Faculty of the College of Engineering and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August, 1997


Winfred M. Phillips
Dean, College of Engineering


Karen A. Holbrook
Dean, Graduate School

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